HRAI

YOUR ENVIRONMENT OUR EXPERTISE

RESIDENTIAL HEAT LOSS & HEAT GAIN manual

Building Science

Heat Loss Calculations

Heat Gain Calculations

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RESIDENTIAL HEAT LOSS AND HEAT GAIN CALCULATIONS

2018 Edition

FOREWORD

Careful use of this Manual should result in satisfactory sizing of heating and cooling equipment. However, the end result is in no way warranted by the Heating, Refrigeration and Air Conditioning Institute of Canada.

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PREFACE

The residential heating system must be selected and designed to provide comfort conditions in all occupied spaces regardless of the season. Temperature, humidity, air movement and ventilation must be controlled by the system. In addition, the system must perform these functions at maximum efficiency in order to minimize energy consumption.

This edition of the HRAI Residential Heat Loss and Heat Gain Manual is based on the third edition of the Canadian Standards Association CAN/CSA-F280-12 "Determining the Required Capacity of Residential Space Heating and Cooling Equipment" published in 2012. The establishment of the capacities of heating and cooling systems for Canadian houses began with the publishing of the first edition of the standard in 1986.

Major Changes to the CSA standard include Microsoft Excel spreadsheets linked to the standard for calculating heat loss associated with all types of common foundations. Also heat loss and heat gain factors needed for determining air leakage rate of the building. Additional changes include calculations for determining heat loss and heat gain due to continuous mechanical ventilation based on the type of ventilation system used.

Heat Loss and Heat Gain calculations are the basis for system design. Heat Loss and Heat Gain must be analyzed if the furnace, boiler or unitary heaters, condensing unit, fans, coils, ducts and air terminals are to be sized correctly. Comfort, efficiency and reliability are closely related to correct sizing and selection of equipment.

A Heat Loss calculation must be done for each room so that the room heating requirements can be determined. Heat Loss and Heat Gain calculations are needed for sizing unitary heaters, outlets, blowers and ducts. Whole house calculations are necessary for the entire structure in order to properly size the heating and cooling equipment.

When equipment is oversized, efficiency is reduced, operating costs are increased and control over space conditions is lessened. Optimum efficiency and control occur when the equipment operates at full load for long periods of time. Since full load conditions occur only a few times per year, properly sized equipment operates at over capacity and reduced efficiency most of the time. Over sizing of equipment aggravates this situation even more. Over sizing of equipment causes short cycles and discomfort.

HOW TO USE THIS MA

This workbook takes a step-by-step approach to load calculations. It deals individually with the various elements that make up a heat loss or heat gain calculation before putting all these elements together. This approach is taken in order to provide you, the learner, with an understanding of why the calculations are done the way they are, as well as learning how to do them.

There are two main segments to the calculation procedures. They are heat loss calculations and heat gain calculations. Heat loss calculations are dealt with first since they are most commonly used. Heat gain calculations follow fairly simply from the heat loss calculations since they use much of the same information and methods.

Load calculations require access to a great deal of data such as climatic conditions, properties of materials, etc. All this necessary information is provided in the appendices located at the back of this course manual. The appendices may appear formidable but this is because enough information is provided to allow heat loss and heat gain calculations to be carried out for almost any location in Canada. The calculations for a single building require only a small fraction of the information in the appendices. This manual explains when certain information is required, where in the appendices to find it, and how to use it.

One important note to keep in mind is that in order to successfully complete a full heat loss and gain calculation, the use of Microsoft Excel spreadsheets linked to the CAN/CSA F280-12 standard must be utilized. They provide critical foundation heat loss and air leakage outputs necessary to complete these calculations. This manual walks the designer through each input required in the spreadsheets including examples of complete spreadsheets.

This manual should not be used to calculate heat loss and/or heat gain for commercial, industrial or institutional structures. Residential designs which include solariums, atriums, swimming pools and hot tubs are a few examples of unusual construction that may require additional consideration. Active or passive solar homes and underground homes are also excluded

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1 Building Science

Heat loss and gain calculations for residential building envelopes are necessary in order to properly size the capacity of heating and cooling equipment. In addition, the distribution system is based on these calculations and as a result, greater accuracy will lead to greater occupant comfort. The understanding of how the design and construction of the building envelope affects its performance is also important. Many aspects of the construction are beyond the control of the HVAC designer, but must be considered in order to provide appropriate levels of comfort to the occupants, and ensure that the dwelling remains durable. There is no substitute for careful consideration of the applicable building science principles, and their communication to contractors and homeowners.

1.1 Comfort Principles

What is Comfort?

A comfortable environment is an environment which is not offensive to any of the following senses: sight, sound, touch and smell. Equipment that is installed to provide comfort should be designed with an acceptable appearance based on its intended use. Operating noise should be low and not noticeable against background or environmental sounds. Undesirable contaminants should not be added to the air by the equipment. Humidity, velocity and the temperature of air should be controlled to prevent the feeling of hot or cold.

Comfort is a subjective concept to some degree and varies with each individual. Thermal comfort, which is the satisfaction with the thermal environment (i.e. feeling too cold, hot, sticky etc) is a primary reason for installing heating and cooling systems. Temperature and humidity are two of the most important factors that determine what is considered acceptable comfort. For example, "Increased relative humidity reduces the rate at which perspiration can evaporate from the skin, and therefore the amount of heat the body can reject.

Consequently, higher relative humidity is generally experienced as a feeling of higher temperature."

ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) has a defined comfort zone for the summer and winter seasons. **Figure 1** provides a simplified version of the ASHRAE Comfort Zone chart as published in ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy). The effect of feeling a higher temperature with high relative humidity is evident by the slanting boundaries of the comfort zone for the upper and lower temperature limits.

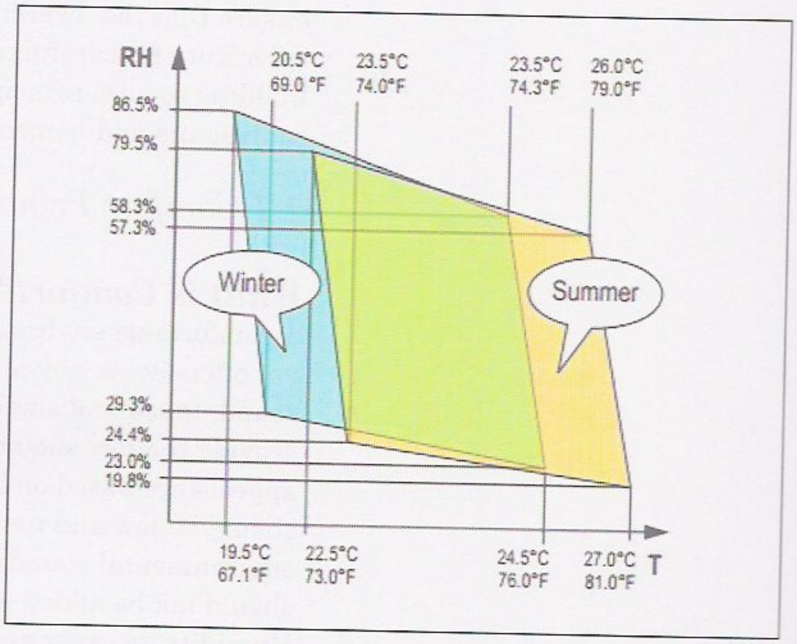
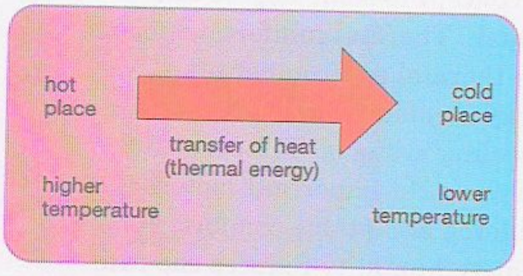


Figure 1 - ASHRAE Comfort Zone Chart

Heat



All objects contain heat. Heat is the transfer of energy from one medium or object to another or from an energy source to a medium or object. A hotter object placed next to a cooler object will always transfer heat from itself into the cooler object, until both objects are of equal temperature. Therefore, heat travels from hot to cold.

Specific Heat

The amount of energy required to change a unit mass of a substance by one degree in temperature.

Example: For dry air, it would take 0.240 Btu (253 J) to raise the temperature of 1lb (.454 kg) of dry air by 1°F (0.56°C). Therefore, the specific heat for dry air is 0.240 Btu/lb °F (1005 J/kg °C).

British Thermal Unit (Btu)

The quantity of energy required to raise the temperature of 1 lb (453.6 grams) of water 1 °F (0.56 °C).

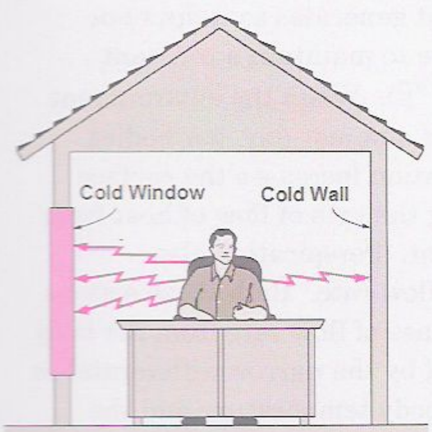
Power and Energy

$$\text{Power} = \frac{Energy}{Time}$$

The terms Power and Energy are often confused. Power is the rate at which energy is used. Power is the measure of how big an appliance has to be, whereas energy is how much it costs to use the appliance. The size of the heating (or cooling) equipment must match the rate at which heat energy is lost (or gained) from the house. This is power and is typically expressed as either BTU/hr (Imperial Units) or Watts (Metric Units). The amount of energy used for a given task, for example the gas or electricity required to heat a house for an entire winter, is energy and is expressed as BTU (Imperial) and Joules (Metric).

1 BTU/h = 0.293W
1 Watt = 3.412 BTU/hr

1.2 Factors Affecting Body Heat Loss



Under normal conditions which are comfortable indoors, the human body loses approximately 91 W (70 W sensible + 21 W latent) or 310 Btu/h (239 Btu/h sensible + 71 Btu/h latent) of heat. There are three main factors of the environment that affect the rate of body heat loss. The three factors are:

- **Temperature**
- **Air Movement**
- **Relative Humidity (RH)**

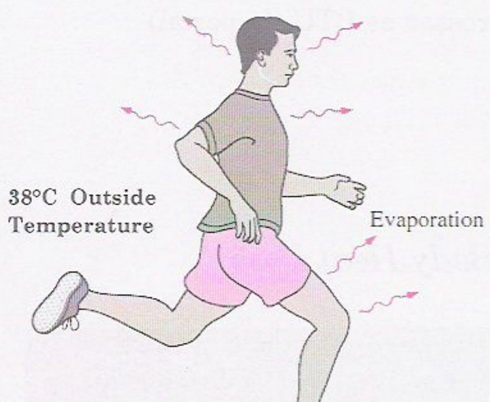
Temperature

The rate of body heat transfer is dependent upon the temperature difference between the body and its surroundings. Air temperature is considered to have the greatest influence on body heat loss.

When room air temperature is low, there is a large temperature differential between the human body and the room. This temperature difference causes an increase in the heat transfer rates. When the room air temperature rises, heat transfer slow down causing the human body surface temperature to rise. This results in less heat flow to the room from the human body.

Air Movement

In order to better understand how air movement increases or decreases the rate of flow of heat losses from our body, we must understand some facts about our bodies and the environment that our bodies function in. The human body generates heat. The amount of heat generated by the body keeps the body temperature higher than its environment under most normal conditions. The human body has very little storage capacity for the heat that it generates, so it must find ways to dissipate that heat in the summer when the body is exposed to high environmental temperatures. Similarly, ways must be found to retain body heat in the winter when the body is exposed to colder environmental temperatures.



Two simple examples illustrate these facts. In the summer, we wear less clothing because we want the body to dissipate the heat it generates so it does not overheat. Our bodies strive to maintain a constant temperature of 37 °C (98.6 °F). When the environment gets hotter such as on a hot summer day, our bodies begin to perspire. Perspiration increases the surface area of the body increasing the rate of flow of heat from the body to the environment. Perspiration also increases the evaporation flow rate. Both these actions help to overcome the decrease of flow rate from the body to the environment created by the narrow differential in temperature between the body temperature and the temperature of the summer environment.

Conversely, in the winter, when the environmental temperatures that the body is exposed to are colder, the greater differential in temperature creates an increase in the heat flow rates from the body to the environment. In order to counteract the greater flow rates and maintain a constant body temperature, we wear more clothes. The clothing acts as an insulator counteracting the increased flow rates created by the greater temperature differentials of winter.

To this point, we have looked at how simple environmental conditions can affect the heat flow rates from the body. We have also looked at ways in which we can assist the increase or decrease of these flow rates (i.e. add or remove clothing) in order to control the amount of heat lost or gained by the body. Now we shall take a look at another condition that can affect body heat flow rates. This is air movement.

Air movement has an effect on the rate of heat flow from the body due to three conditions. The first condition is, as stated earlier, that the body generates a large amount of heat and has no effective means to dissipate it. The second condition is that air does not have an ability to hold a lot of heat (about one quarter of the ability that water has) so, therefore, we must pass a large amount of air over the body to absorb the body heat.

The third condition that affects the rate of heat flow, particularly in buildings, is the fact that air currents or flows vary in different parts of the building. If you are located in a drafty area, then you will feel cooler than if you were away from the draft. For example, when you are near a fan in a 22 °C (72 °F) temperature room, you will feel cooler than you would in the same room away from the fan where little or no air flow is taking place.

Higher velocities of air passing over the body cause a higher rate of convective and evaporative heat flow, resulting in a greater body heat loss.
It is important to understand the difference between the concept of air passing over our body and providing a cooling effect and the concept of our ability to absorb

heat. For example, if we have a large number of people in a room such as a theatre and we pass the same air over the occupants of the room, then eventually, the room temperature will increase. As the room temperature increases, the air passing over our bodies will get hot and the convective and evaporative heat flow will be lost. It is important to keep in mind that air movement is only effective in reducing body heat loss when the air being used has an ability to absorb heat and moisture.

Relative Humidity (RH)

Relative humidity is the ratio of the amount of water vapour present in the air to the greatest amount possible at the same temperature.

Body heat loss is influenced by relative humidity but to a lesser degree than by temperature and air movement. When the relative humidity is low, air will absorb moisture from the body more readily and increase the rate of evaporative heat loss.

When the relative humidity is high, the opposite will occur and the rate of evaporative heat loss will be slowed down.

Dew Point Temperature

The Dew Point Temperature is the temperature at which the air becomes saturated with water vapour. As the air temperature is lowered below the dew point, condensation of water vapour to visible water takes place. An example is the sweating on a glass of ice water. The cold glass reduces the air temperature below its dew point, and the moisture that condenses forms beads of water on the glass surface.

1.3 Sensible and Latent Heat

In order to understand sensible heat and latent heat, we must first have an understanding of two other terms. These terms are *substance* and *state.*

Substance

Air is a substance. It is a substance because it consists mostly of oxygen and nitrogen. Water is a substance because it is made up of hydrogen and oxygen.

State

For our purposes, state is the condition in which we find a substance. For example, water and ice are the same substance, but they are in different states - liquid for water and solid for ice.

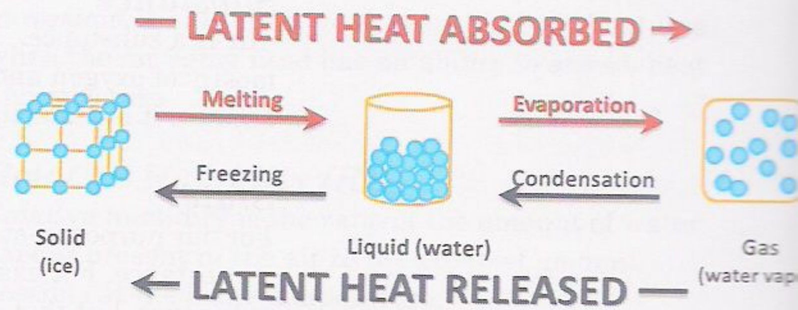
Sensible Heat

Sensible heat is heat that will change the temperature of a substance without changing its state. Sensible heat is measured with a thermometer. Water that is heated from 20 °C (68 °F) to 35 °C (95 °F) does not change its state. It remains a liquid. Because this change in temperature can be read with a thermometer, the heat involved is sensible heat. The reverse is also true, if the water was cooled, the amount of heat removed is sensible heat.

Latent Heat

Latent Heat is the heat required to change the state of a substance without changing its temperature. An example of latent heat is when a solid such as ice, changes to liquid in the form of water. It takes 144 Btu (152 K Joules) of latent heat to change one pound of ice at 32 °F (0 °C) to one pound of water at 32 °F (0 °C). Again, the reverse is also true. If you had a pound of water and removed the same amount of heat, it would turn to ice at the same temperature.

The energy required to evaporate or condense water is called the latent heat of evaporation. It is 964 Btu/lb for water. The energy required to freeze or thaw water is called the latent heat of fusion. It is 144 Btu/lb for water.



Modes of Heat Transfer

In heating and air conditioning, the goal is to prevent the inside of the structure from becoming too cold in winter or too warm in summer. If the inside temperature is to remain constant, the cooling and heating systems must remove the heat that comes into the structure or replace the heat that is lost from the structure. Since heat is continuously transferred, we must know how much heat is transferred in a given time period. One hour is the time period commonly used. Therefore, heat loss and heat gain is calculated in Btu/h in imperial units or watts in the SI system

1.4 How Heat Transfers

Heat transfer is driven by a change in temperature and heat flows from a higher temperature to a lower temperature. The same can be said for wind and water currents from the higher pressure to the lower pressure regions. The transfer of heat from the human body to its surroundings occurs when the surface of the body is at a higher temperature than that of its surroundings.

The building envelope is made up of assemblies that separate the conditioned from the unconditioned spaces. Those exposed assemblies typically include ceiling, walls, floors, headers, doors, and windows.

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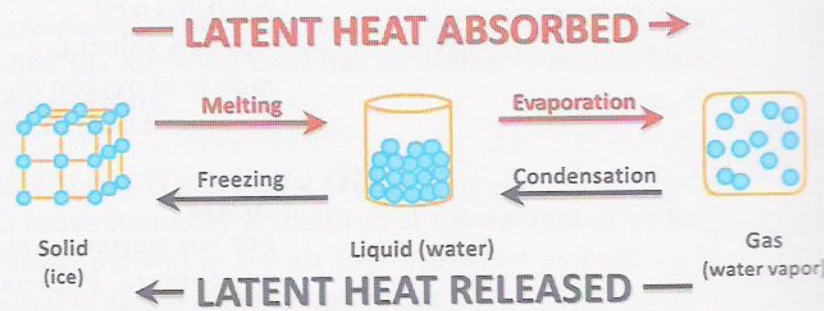

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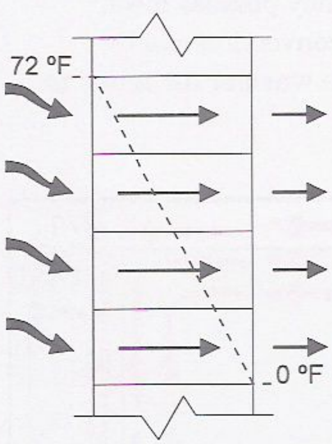
There are three modes of heat transfer and frequently a combination of two or more of these are involved in the Heating, Ventilation and Air Conditioning (HVAC) industry.

The three methods are:

- **Conduction**
- **Convection**
- **Radiation**

Conduction



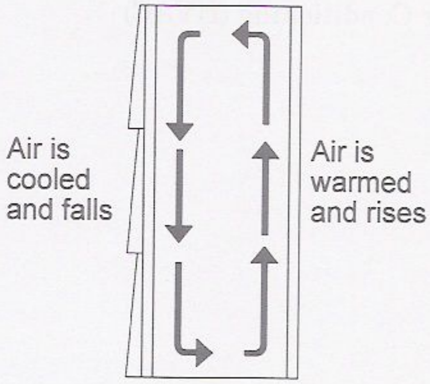
Conduction is the flow of heat through a solid object or through objects in contact with each other. Heat can be conducted through a wall. Another example is when the heat from a cast iron frying pan is transferred to the handle and eventually to your hand.

Conductivity is a material property. Materials that are good conductors of heat, such as metals, have high conductivities. Insulation materials, such as fiberglass have a low conductivity and are poor conductors of heat. Thermal Resistance or R value is the inverse of conductivity. Something with a low conductivity has a high R value and is a good insulator.

Since conduction is heat transfer through a component, it is dependent on the size as well as the R value of the component. In fact the equation for conductive heat loss is very simple and given below:

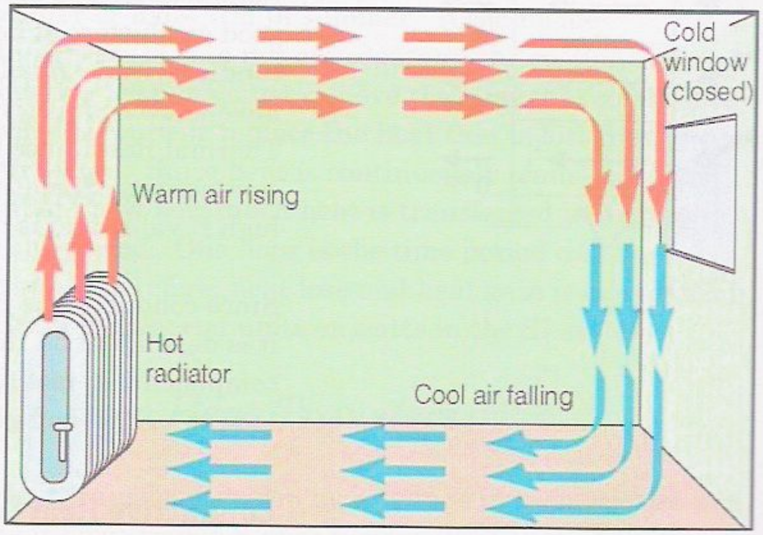
$$\textbf{Conductive Heat Loss} = \frac{\textbf{Heat Loss } \Delta \textbf{ T x Area}}{\textbf{R−Value}}$$

Convection



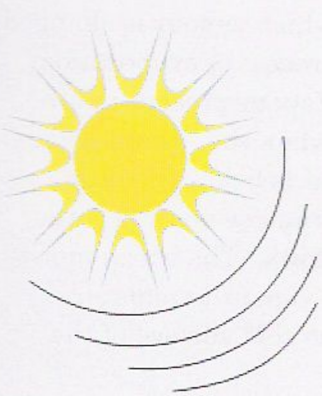
Convection is the transfer of heat that takes place within moving liquids and gases. An example is the heat carried by air after it has passed over a heating coil or heat exchanger in a heating unit. Convection is dependent on several parameters including fluid properties (density, viscosity, thermal conductivity, and specific heat capacity), temperature and fluid speed.

Convection is classified as natural or forced. Natural convection occurs in the absence of a "forcing" mechanism such as fans (to move gases) or pumps and circulators (to move liquids). Natural convection happens by density variations due to variations in temperature with height. For example, heated liquids or gases tend to move upward, as they possess lower density. An example of natural convection can be observed inside the house, where warmer air tends to move to upper stories



Natural Convection

Forced convection, as one can gather from the description above for natural convection, is the mechanism of transporting gases or liquids by means of external source or "forcing" mechanism such as a fan moving air over a coil. It is a much more efficient method of heat transfer than natural convection as significant amounts of heat energy can be transported very efficiently.



Radiation

Radiation is the transfer of heat from the surface of a hot object to the surface of a cooler object by electromagnetic waves, such as infrared light. Radiation does not heat the air that it passes through, but does heat any objects that it may strike, such as the human body, floors, furnishings and walls. Examples of radiant heat transfer include: the warmth felt while sitting near a fire, or being exposed to the sun. When you stand in front of a cold window in winter, you are radiating heat to the window and you experience the feeling of being cold, even though the surrounding room temperature is high.

1.5 The States of Matter

The change of state always occurs with a change of heat. Heat either goes into the material (heat gain) during a change of state or heat comes out (heat loss) of the material during this change. However, although the heat content of the material changes, the temperature does not. There are two modes of state change that are of concern and are used in heat loss and heat gain calculations. These modes are evaporation and condensation.

Evaporation

Evaporation is the process by which moisture is changed into a vapour. This process involves Latent Heat. As the moisture evaporates from a warm surface, heat is removed and the surface is cooled. An example of evaporation is the "cooling" felt when stepping out of a hot shower. It takes your body heat to evaporate the water, which gives a sensation of cooling.

Condensation

Condensation is the process by which vapour is changed into liquid. This is the reverse process of evaporation but still involves Latent Heat. Vapour present in air will change into water droplets when the vapour comes in contact with a cool surface that is below the dew point. An example of this heat transfer method is the condensation that forms on windows. The warm moist air in the building changes from vapour to moisture when it comes in contact with the cold surface of the window.

1.6 The Building as a System

Building

A building is a structure consisting of a roof, walls, windows, doors and many other components which collectively provides the occupant with shelter from the weather.

- A building is also a "System".
- A system consists of a number of distinct parts or components. All of the components are linked together so that a change in one usually causes changes in others. A component may be a sub-system, comprised of a number of sub-components that are also related to each other.
- Systems are everywhere. We deal with systems every day and whether we know it or not, the only way we begin to understand how hockey teams, offices, factories, cars and many other things work, is by approaching them as a system recognizing that they consist of several parts and understanding how the parts are related. Systems are dynamic. They are changing constantly in response to outside forces. Each time a change is made to a component, the system is affected.
- The same is true for a building. The building is a system and a systems approach is essential in order to understand how it works.

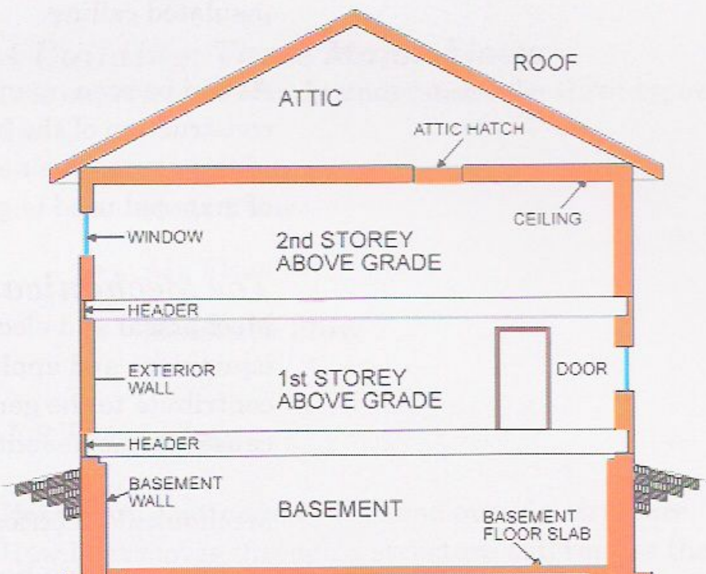
1.7 The Components of a Building

The house consists of three major components - the building envelope, the mechanical systems and the occupants.

The Building Envelope

The building envelope consists of the upper ceiling(s), walls, windows, doors, basement walls and the basement floor - all exterior assemblies that separate the indoors from the outdoors.

The building envelope separates the indoor & outdoor environment. The better it is insulated and air sealed, the less heat, air & moisture transferred. It is predominantly the building envelope which determines the rate of heat loss under design conditions.



Note: The building Envelope is shaded in the drawing.

A building is made up of many different assemblies. Looking at the outside of the building you might see a brick veneer, metal or wood siding. However, behind the exterior cladding there might be an air space, sheathing, studs, insulation and an interior finish of drywall or lath and plaster. A vapour and air barrier might also be part of this wall. This is just one type of constructions of an above grade wall. There are many other types.

Part of Building Science relates to understanding the different components that are used in an assembly and the effect these components have on the transfer of heat, air and moisture.

The construction of the below grade portion of the building must also be considered. This might be of concrete, concrete block, or of wood construction. Insulation and vapour barriers are generally a part of this structure. The roof of a building can be built in many ways using different materials. An example might be a building with a vented attic above an insulated ceiling.

As can be seen, many types of materials may be used in construction of the building envelope. For the purposes of this course, we need to know the type and thickness of material used (e.g. type and thickness of insulation).

The Mechanical Systems

Mechanical and electrical systems include all the equipment and appliances in a building which contribute to the generation of heat or moisture, or cause the movement of air.

Mechanical/Electrical equipment includes:

- **space heating equipment**
- **domestic water heater**
- **air cleaners**
- **exhaust fans**
- **lighting**
- **stoves**
- **fireplaces and woodstoves**
- **refrigerators**
- **dryers**
- **motors and other appliances**

A furnace, for example, is designed to add heat to the building. Other appliances are intended to serve a completely different function, but still add or remove heat, air or moisture to or from the building. A fridge, for example, adds heat while a dishwasher will add heat and moisture.

An important point to remember is that all the equipment and appliances add, transfer or remove heat, air or moisture to or from the building envelope.

The Occupants

A third and very important component of the building is the occupants, including all people, pets and plants living in the building. They release heat and moisture into the indoor space. They also control the operation of the mechanical equipment and to some extent, the building envelope (for example, when opening and closing windows and doors).

A Building: Three Major Flows

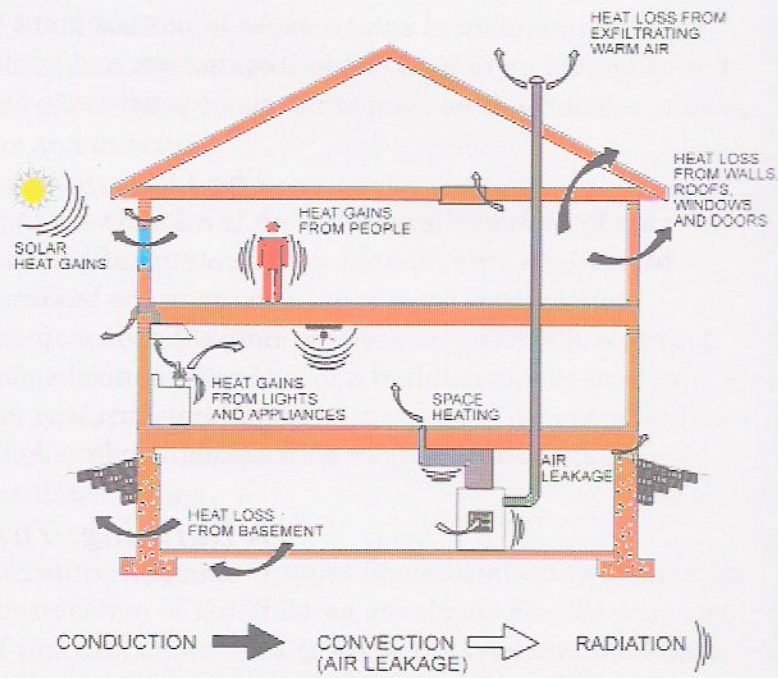
It is important to clearly understand the three types of flows.

- **Heat Flow**
- **Air Flow**
- **Moisture Flow**

1.8 Heat Flow

Heat flows continuously into and out of a structure. How heat moves through a structure determines the operating cost and, to a large extent, the comfort of people in the structure. Heat also acts as one of the "driving forces" behind the movement of air and moisture.

Gaining an appreciation for the total heat flow throughout a building may seem complicated. However, understanding the heat flow is actually quite straightforward. The drawing illustrates heat flow in a building. Heat moves continuously into, out of and throughout the building by conduction, convection and radiation. Heat movement through the building envelope consists of "heat gains" and "heat losses" that can be quickly identified in any building.



Heat Balance

All heat produced in the structure, by the heating equipment, people, sun and appliances will eventually be lost to the outdoors. The amount of heat added must be equal to the amount lost if the indoor temperature is to remain constant.

Heat is always moving. Heat flows from a substance or space at a higher temperature to a substance or space at a lower temperature in any direction.
Heat will flow in one direction until a "balance" is achieved. This "balance" is when they are both at the same temperature. If a substance is to remain at a constant temperature, any heat flowing to a colder substance must be replaced by exactly the same amount of heat.

A building provides an ongoing demonstration of these principles. In winter, heat moves constantly from inside the structure, where it is warm (hot) to the cooler (cold) outdoors. This flow will continue until the indoor temperature is equal to the outdoor temperature

Heat Losses

Heat passes through the building envelope by conduction, convection and radiation. These three modes work closely together. For example, heat absorbed by the interior surface of an uninsulated wall moves by conduction through the drywall or plaster. It is then picked up by natural convection currents and carried over to the exterior sheathing. Some heat also radiates into the empty cavity. Eventually, the heat is absorbed by the exterior cladding and is radiated or conducted to the outdoors. The wind also removes heat from the exterior cladding by convection.

Heat also flows out of the building through the flues of the furnace, fireplace or any other combustion appliances. The draft has the effect of pulling heated air out of the building

Bathroom and kitchen exhaust fans, dryer vents and any other exhaust equipment also expel heated air and moisture.

Heat Gains

How is heat contributed to a building? Traditionally solar energy, in the form of heat, flows into the building by radiation through windows and other transparent parts of the building. Solar radiation is also absorbed by the roof, walls and other surfaces of the building envelope. It then moves by conduction through the building envelope and is radiated into the building.

> The majority of this solar heat gain comes through your windows, glazed doors, and skylights. The most effective way to manage the amount of solar gain that enters your home or office is to block it before it gets into the building.

Solar gains are significant. About 10% to 20% of the heat required to keep a typical building warm throughout the winter comes from the sun. However, this percentage can vary from building to building and from day to day.

Internal gains include all of the heat released into the building by lights, appliances, plug loads and also people and their activities.

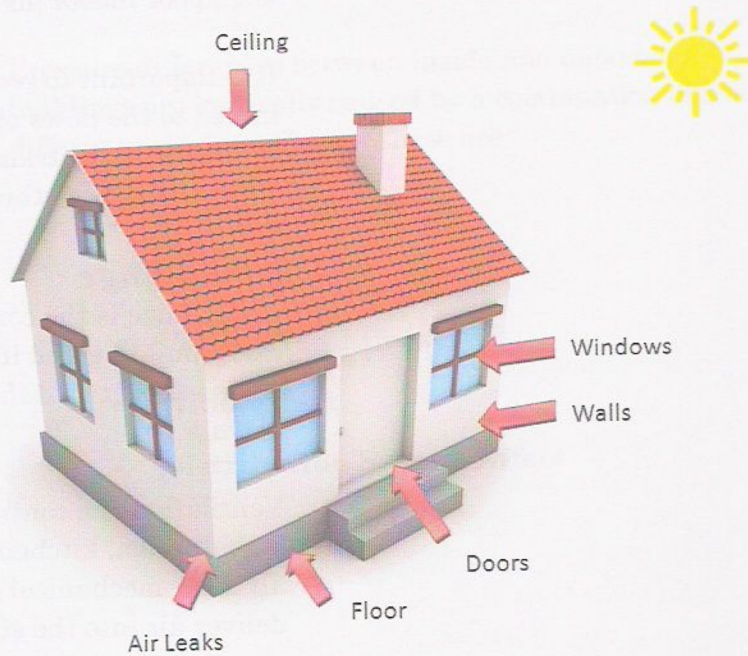
These internal gains are also significant, making up about 10% to 20% of the heat required by a typical building during the winter. However, percentages can vary from building to building and from day to day.

In most residential buildings, the heating system generates the largest flow of energy into the building. The heating system consists of the heating plant (i.e. furnace, boiler or unitary heaters) the heat distribution system (i.e. ducts and registers or pipes and radiators) and heating system controls. Energy initially enters the building as electrical energy in the case of electric heating systems or chemical energy in the case of oil or gas-fired systems. The heating plant acts as an energy converter, changing electrical or chemical energy into heat.

All of the heat produced by an electrical heating unit flows into the building. Some of the heat produced by fossil fuel fired heating appliances enters the building, while some of the heat may flow up the chimney along with combustion gases.

Heat is carried throughout the building by air in a hot air distribution system and by water in a hot water (i.e. hydronic) distribution system. Some heat is lost from the distribution system along the way. Heat is lost by leakage through the joints and holes in duct work and by conduction through the metal walls of the ducts in hot air systems. In a hot water system, heat is lost by conduction through the pipes.

All of the heat entering the building envelope from the sun, internal sources or the heating system is eventually lost to the outdoors during the winter.



The Balance of Heat Gains and Losses

If the indoor temperature is to remain constant, the total amount of heat lost through the building envelope must be equal to the total amount of energy gained from all sources combined.

If the outdoor temperature drops on a cold night, the outward flow of heat increases. Therefore, the rate of heat gain must increase to maintain the "balance" and maintain the indoor temperature. The furnace or boiler is usually called upon to meet the additional demand for heat.

1.9 Air Flow

The second "flow" within the building system is the flow of air. Understanding the air flow is extremely important as it can explain why a number of problems (e.g., poor indoor air quality) are created.

It is important to recognize that the flow of air is closely linked to the flows of heat and moisture. Air acts as a carrier, thereby transporting heat, moisture and many other substances throughout the building.

Air Change

Air Change is the continuous exchange of air between every building and its surroundings. This air change is the result of two different processes: *ventilation* and *air leakage.*

Ventilation is a controlled air change. It can be provided by bathroom, kitchen and exhaust fans, dryer vents and all other mechanical devices that expel air from, or deliver air into the structure.

Air leakage is an uncontrolled air change. It occurs as air flows through cracks, structural joints, gaps around window frames and many other small openings in the building envelope. Infiltration refers to the flow of air from outside the building envelope to inside the building envelope. Exfiltration refers to the flow of air in the reverse direction, from the inside to outside.

Air Pressure

Air leakage will only occur when there is a difference in air pressures between the inside and outside of the building. If there is a hole through a wall, no air will flow through the hole until the pressure on one side of the hole is higher than on the other side.

The air pressure is greater in one space than another if there are more air molecules in an equal volume. The air pressure in a fixed space will drop when air is "sucked out", or rise when air is pumped in. The flow of air will continue from a high pressure area to a low pressure area until the pressures in both areas are equal. The flow of air, like the flow of heat, always tries to establish a balance.

Pressure Effects

As we have seen, differences in air pressure cause movements of air. What then, causes differences in air pressures?

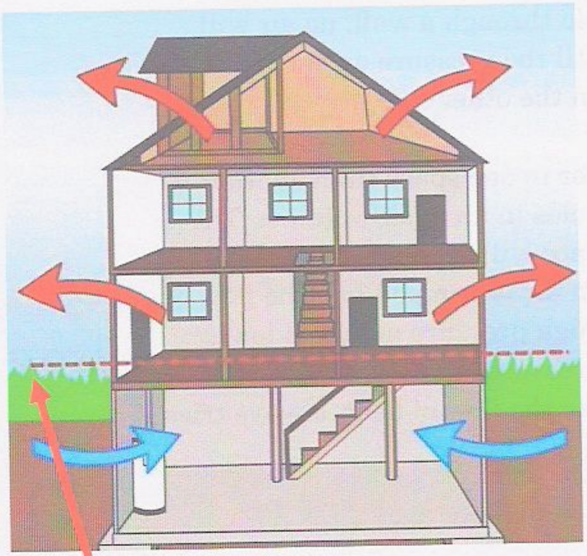
Pressure differences between inside and outside of buildings are generally caused by a combination of five different pressure effects. These are:

Caution:
Under certain conditions, these pressure effects can interfere with the safe venting of fuel fired equipment.

- **Stack Effect**
- **Flue Effect**
- **Ventilation Effect**
- **Wind Effect**
- **Distribution System Effect**

The Stack Effect

When the indoor air is heated, it becomes lighter and rises. During winter, when heat is almost continually added to the indoor space, an upward flow of air is established. The air pressure inside the upper parts of the structure builds until it is higher than the outdoor air pressure. Air will tend to exfiltrate from the upper parts of the building due to the *stack effect*.



NEUTRAL PRESSURE PLANE

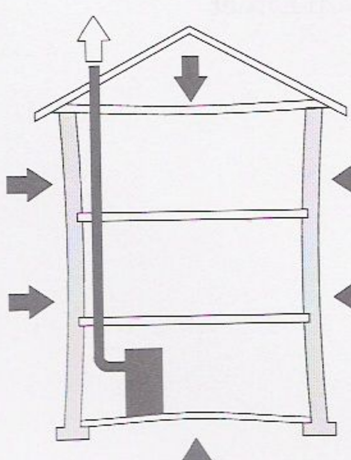
The upward flow of air, draws air out of the lower parts of the building, where the air pressure drops. Air will tend to infiltrate into the lower area to replace the air that has been drawn upward.

The overall result is a continuous air flow, with exfiltration occurring upstairs and infiltration occurring downstairs. At one point, where the air flow changes from an outward to an inward direction, there is no pressure difference between inside and outside. This can be described as a flat surface cutting across the building and dividing it into two parts: one with high pressure and one with low pressure, relative to the outdoors. This dividing surface is known as the "neutral pressure plane".

It should be noted that there is a Stack Effect in the summer as well except it is called Reverse Stack Effect since the outside temperature is warmer, and therefore more buoyant, than inside.

The Flue Effect

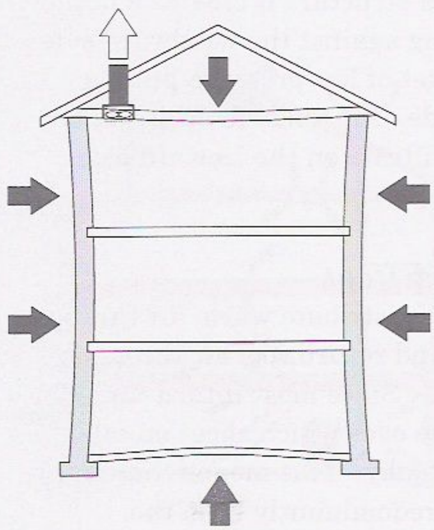
The *flue effect* occurs in all houses with an open chimney flue serving a naturally aspirating combustion appliance such as a furnace, boiler, domestic water heater, fireplace or woodstove.



Combustion gases, which are hotter than the house air and have a low density, rise rapidly up the chimney flue creating a strong upward draft. This draft sucks air out of the house, reducing the indoor air pressure. Air will then infiltrate into the house from outside, where the air pressure is higher.

The flue effect is strong only when there is a significant draft up the chimney. When combustion stops, the flue will cool down and the draft will weaken. The neutral pressure plane will rise and fall with each cycle of a combustion furnace or lighting of a woodstove, fireplace, etc.

The Ventilation Effect



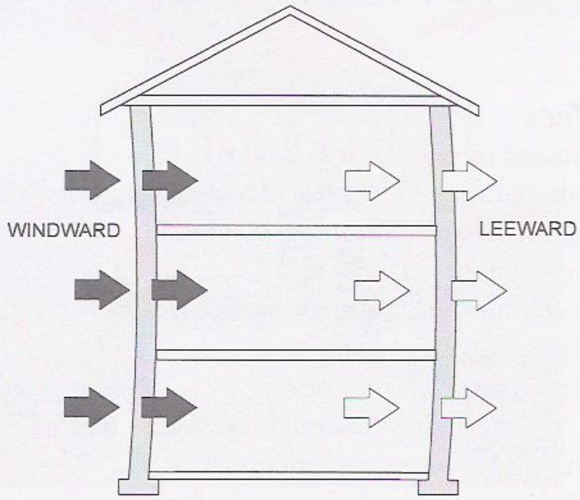
Most buildings have a number of mechanical devices that exhaust air. Common examples are heat recovery ventilators, bathroom fans, kitchen range fans, clothes dryers and central vacuum systems. There could also be other devices installed in the building which have greater exhaust capabilities than any of those mentioned and careful attention to all exhaust appliances is important. These devices, when operated, expel air from the building and reduce the indoor air pressure. Some of these devices may include supply fans that bring in fresh air at the same time as they exhaust and will have minimal impact on the pressure in the house, if properly balanced.

The *ventilation effect* is similar to the flue effect. It is a force that, by reducing or increasing indoor air pressure, causes air to infiltrate or exfiltrate.

The neutral pressure plane, as explained previously, tends to rise whenever the indoor air pressure is reduced. The operation of mechanical exhaust devices will therefore cause the neutral pressure plane to rise.

When a building is operating normally, with the furnace cycling and the various ventilation devices being used intermittently, the stack effect, flue effect and ventilation effect may combine to create a powerful exhaust of air out of the structure. The indoor air pressure during these periods will be reduced so low that large volumes of air must infiltrate to replace the exhausted air. The combined effect is strong enough to overcome the high pressure built up in the upper part of the building by the stack effect. The air pressure, even in the upper floors, is reduced to the point where air is drawn inward through all parts of the building envelope. In some commercial buildings a means of

mechanically supplying make-up air may be required. This condition can be so powerful that the whole structure has a lower air pressure than outside, even at the very top of the envelope. The neutral pressure plane under these conditions rises above the building envelope.



The Wind Effect

When wind blows against a structure it creates a pocket of high air pressure pushing against the windward side of the structure and a pocket of low pressure pulling outward on the leeward side. Air tends to infiltrate on the windward side and exfiltrate on the leeward side.

Distribution System Effect

Forced-air heating systems distribute warm air through pressurized supply ducts and return cool air through depressurized return ducts. Since most return-air systems utilize a joist space over which sheet metal is nailed, it tends to be very leaky. This means that many return systems draw air predominantly from the basement, creating a negative pressure. The effect can be compounded by basement return-air inlets, poor fitting external furnace filter assemblies, and leaky furnace blower doors.

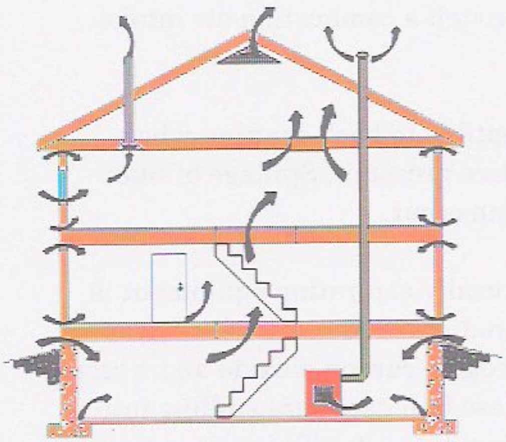
Individual rooms can be pressurized if there is insufficient return capacity in the form or door undercuts, transfer grills or dedicated returns.

Finally, any supply ducting that is installed outside the building envelope will effectively exhaust air from the building if it has any leaks, creating a negative pressure. Conversely any return ducting would bring air into the building, creating a positive pressure.

Overall Air Flow

When it is cooler on the outside than on the inside of a typical building, the overall air flow pattern consists of natural infiltration in the lower part of the building, and natural exfiltration in the extreme upper part. This basic pattern is distorted whenever a flue or exhaust device operates, or when the wind blows.

It is very important to recognize that the five pressure effects and the pressure patterns they create are not fixed - they are constantly changing. During any 24 hour period, each part of the building will be exposed to pressures of varying strength and direction as combustion systems cycle, mechanical exhaust equipment is turned on and off and the winds change in speed and direction.



In buildings with forced air heating, air is circulated mechanically throughout the building by the blower fan and duct system, which can further impact the pressures in the house, or individual rooms.

Discussion thus far has assumed that buildings have some form of combustion heating system and some form of mechanical ventilation equipment. In practice, however, it is not uncommon to find buildings that have very poor ventilation systems and no combustion appliances or duct system. In such instances, the building may have no flue effect, distribution system effect and very little ventilation effect. The pressure patterns around the building will be determined almost entirely by the stack effect and the wind effect. There will be a higher indoor air pressure and a more dominant outward flow of air.

In residential applications there is such a wide range of conditions that may be encountered that it is almost impossible to discuss it here, but it should be remembered that poor ventilation conditions are common in residential applications and all of the above conditions should be taken into account when looking at a residential building.

Combustion Venting Safety Considerations

In a great number of buildings, the demand for space heating and domestic hot water heating is supplied by fuel fired equipment using natural gas, propane or oil.

Fuel fired equipment that relies on a flue to exhaust products of combustion by flue effect are called naturally aspirating. Air for combustion and draft equalization (draft diverter) must be drawn from outside, generally from infiltration of air through the building envelope or through a combustion air intake into the building.

Such systems are susceptible to back drafting when there is excessive negative pressure. Spillage of flue gases into a structure can occur.

If the burner in the naturally aspirating equipment is operating properly, it produces flue gases which are mainly composed of nitrogen, carbon dioxide and water vapour. If, however, these flue gases are spilling into the structure, carbon dioxide levels will increase and the burner may produce carbon monoxide as part of flue gases. Carbon monoxide is an odorless, colorless, tasteless and an extremely toxic gas.

1.10 Moisture Flow

Moisture, like heat and air, flows continuously throughout and around the building. The moisture flow is tied closely to the heat and air flows. It is essential that the flow of moisture be properly managed. Poor moisture management usually results in excess humidity, concealed condensation and other moisture problems that can corrode mechanical equipment and deteriorate the building structure.

Moisture is always present in every building. It exists as a solid. Ice can be found, for example, inside wall cavities. It exists as a liquid; water collects in basements, on windows and many other places in the structure. It also exists as a gas; water vapour is always present in the indoor air. Moisture is constantly changing between these three states.

Relative Humidity and Condensation in Buildings

Definitions of *Relative Humidity*, *Dew Point* and *Condensation* found in prior text should be clearly understood to appreciate the following example.

The basic relationships between temperature, relative humidity and the dew point are illustrated every day in almost every building.

During winter, the relative humidity of the cold outdoor air can be much higher than the relative humidity inside the structure. This is because the temperature is much lower and not because there is more water vapour in the outdoor air. In fact, in most cases there will be more water vapour in the cold outdoor air than in an equal volume of warm indoor air.

When cold outdoor air leaks into the structure through cracks and leaks in the building envelope, it is heated very quickly. The relative humidity drops dramatically. Outdoor air, at a temperature of -10 °C (14 °F) and a relative humidity (RH) of 80%, moves into the house where it is heated to 20 °C (68 °F). The RH drops to 10%.

This explains why many buildings seem dry during the winter and why humidifiers are needed (the humidifier adds moisture to the indoor air). It is also important to understand that any measure used to reduce the flow of dry air into the structure will allow the indoor humidity to build, even without the addition of a humidifier.

Furthermore, it should be noted that the exfiltrating, moist air may damage the building envelope.

NOTES:

2 Heat Loss Calculations

Purpose of Chapter

This section examines the steps involved in determining the heat loss in residential buildings using the HRAI Residential Heat Loss and Heat Gain Calculations worksheet. Where possible, Example-01 will be used to relate between the procedures presented in this section and how these are applied using the worksheet.

Table of Contents

2.1 Introduction

When preparing a heat loss calculation, the procedure to be followed will be dependent on whether the designer is dealing with a new or an existing building. For new buildings, a set of plans showing the construction and dimensions will be required. This information will be used to determine the areas of walls, windows, doors, floors, ceilings, etc., and their corresponding thermal resistance values (R-values). For cooling load calculations (see Chapter 3), the occupant load, internal heat gains and the direction the building is facing will also be required.

For existing buildings, it will be necessary for the designer to visit the building and obtain all necessary measurements and information. In some cases, such as major renovations, a set of drawings may have been prepared and be available. It is advisable to check for any critical changes to the building not shown on the plans, such as changes to window sizes or R-values, or the addition of windows or glazed doors.

When a completely new heating system is being installed, it is necessary to define each of the rooms or zones to which heat will be supplied. Normally, zones correspond to rooms, however, areas such as entries, separate rooms in basements, and open plan family/living/dining areas may have to be treated according to how the space heating will be delivered to them. For example, if forced air heating is being delivered to a basement with a den and a bathroom, it is necessary to treat each of these as a separate room in order to accurately determine how much heat must be delivered to each of them.

It is also important to assign areas of the dwelling where no heating will be supplied; such areas include interior hallways which must be added to adjacent rooms which are heated. Otherwise, the whole house heat loss will be underestimated. This aspect of dealing with heat loss calculations will require judgment based on experience.

Once all of the building information has been obtained, and the individual rooms or zones have been designated, the designer is ready to proceed with the processing of the Residential Heat Loss and Heat Gain Calculations worksheet. In practice, you will normally require information from the Appendices in this manual.

Note: There are three sets of appendices.

1. A-B-C Imperial Units (green)
2. A-B-C SI (Metric) Units (blue)
3. D Temperature Data for Locations Across Canada in both Imperial and SI Units (yellow)

Begin by taking an HRAI Residential Heat Loss and Heat Gain Calculations worksheet, page 1.

First, fill in the project building location information which includes:

i) Model

ii) Address

iii) City and Province

iv) Postal Code

v) Project Building Site & Lot

Then, complete customer and designer information as it applies.

Next, fill in data and assumptions for heat loss and heat gain calculations that are listed in Section A, Building Construction Details. In this section, a designer is asked to fill out information such as building plan & drawing number and building characteristics which includes front facing direction, air tightness, shielding and etc.

A designer also needs to enter simple structure label and corresponding descriptions for building envelope assemblies (e.g. walls, floors, ceilings, doors, windows and skylights) under “Building Envelope Assemblies”.

2.2 Design Conditions

- **Section B, HRAI Residential Heat Loss and Heat Gain Calculations, page 2**

Step i) Decide which units will be used throughout the entire calculation procedure.

Step ii) From Appendix D, for the location where the building is situated, transfer the following information into Section B, Design Conditions, Heat Loss Column, page 2 of the worksheet:

In this manual, mean soil temperature is used as deep ground temperature.

a) Outdoor Design Temperature Heating

b) Mean Soil Temperature

Step iii) From building plans and drawings, identify and calculate the conditioned building volume (V_b) and area of the building, and enter the values into Section B, Design Conditions, page 2 of the worksheet.

Step iv) Identify the ventilation system type from building plans and drawings, and then select the ventilation system that is applicable for the project building.

a) Case #1: Exhaust only system

b) Case #2: Direct ducted system

c) Case #3: Central forced air system

The details on the classification of ventilation system types are discussed in section 2.14 of this Chapter.

Step v) Enter apparent sensible effectiveness of an HRV or ERV that is installed in building ventilation system. If an HRV or ERV has not been installed, enter N/A (not applicable)

Outdoor Design Temperature (ODT)

The Outdoor Design Temperature (ODT) for a given location can be found in Appendix D. This temperature is based on a 10 year average and represents the lowest sustained temperature that might be expected in normal winter conditions. The coldest month is January and 2.5% of the time in January the outdoor temperature may fall below the design temperature, but usually for only a short period of time. For Example-01 house located in Charlottetown, PEI, the outdoor design temperature (ODT) is -20° C (-4°F).

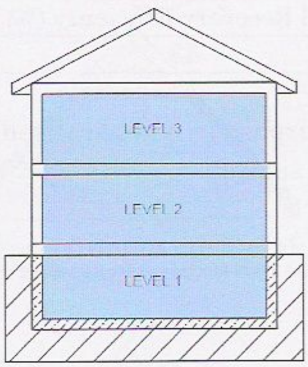
Indoor Design Temperature (IDT)

The CSA F280-12 Standard requires the Indoor Design Temperature (IDT) used in heat loss calculations to be at least the following:

It should be noted that the lowest level in the building is called foundation and the levels above foundation are called second level and third level respectively

Type of Space	Minimum IDT
unfinished basement	18 °C (65 °F)
heated crawl space	15 °C (59 °F)
all other conditioned spaces	22 °C (72 °F)

Therefore, in a typical house, we could use an indoor design temperature of 72 °F (22 °C) for the living areas and 65 °F (18 °C) for the unfinished basement. When doing a heat loss calculation for a particular client who wants to be able to maintain a temperature higher than 72 °F (22 °C) even in the coldest weather, use the indoor design temperature the client wants to maintain. It is often appropriate to calculate a basement at 72 °F (22 °C) so that the installed equipment is adequate when and if the basement becomes living space. In our examples, we will consider the basement to be at 72 °F (22 °C).



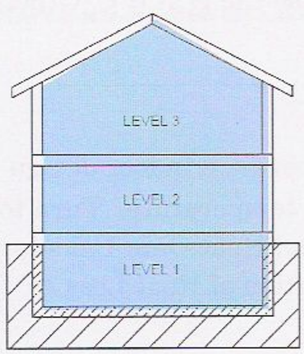
Building volume of a flat ceiling house

Building Volume

The building volume is the total conditioned volume of all levels in the building including volume of the floor between the conditioned levels of the building and the basement if applicable. This is 15,744 ft^3 (= 445.82 m^3) in Example-01.

Building Conditioned Area

The building conditioned area is the total floor area of conditioned spaces in the building. This is 1,536 ft^2 (= 142.70 m^2) in Example-01.



Building volume of a cathedral ceiling house

Apparent Sensible Effectiveness of the HRV/ERV

When the designer is aware that the building's HVAC system includes a Heat Recovery Ventilator (HRV) or Enthalpy Recovery Ventilator (ERV), the heating load due to ventilation can be reduced by applying a factor for the effectiveness of that appliance. The HRV/ERV **apparent sensible effectiveness** is used to predict the temperature of the air discharged from the HRV/ERV into the building.

The performance table from HRV/ERV manufacturer's equipment specification sheet, similar to the sample table provided below, shall be used to obtain the apparent sensible effectiveness.

HRV/ERV Performance Table

	Supply Temperature		Net Air Flow		Average Power W	Sensible Recovery Efficiency (%)	Apparent Sensible Effectiveness (%)	Net Moisture Transfer
	C°	F°	L/s	cfm				
Heating	0	32	20	41	30	65	74	0.47
	0	32	30	64	36	64	71	0.40
	-25	-13	16	35	27	54	80	0.39
						Total Recovery Efficiency (%)		
Cooling	35	95	19	41	30	43		

Note: The above table is only provided for illustrative purpose in a generalized format. Actual specification sheet may differ from above sample.

For actual design load calculations, energy performance data from manufacturer's specifications shall be used.

Note: The apparent sensible effectiveness shall be selected based on the principal ventilation capacity (PVC) or CAN/CSA-F326 for the building at an air temperature closest to the design temperature. (e.g. If design temperature is warmer than or equal to -12°C use the E at 0°C. Otherwise, use E at -25°C.)

Heat Loss ΔT (HL ΔT)

Heat Loss ΔT is the difference between indoor design temperature and outdoor design temperature. Turn to page 3 of the Residential Heat Loss and Heat Gain Calculations worksheet, and begin the calculation of Heat Loss ΔT (HL ΔT) as follows:

HL ΔT = IDT - ODT

For Example-01 : 72 °F – (–4 °F) = 76 °F

or 22°C – (–20°C) = 42 °C

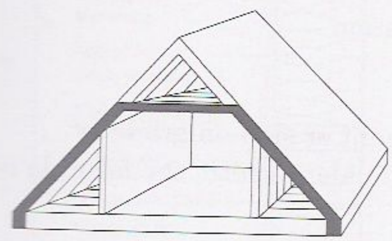
Step i) Calculate HL ΔT and enter it in the space provided at the top left hand corner of page 3 of the worksheet.

Note: The importance of Heat Loss ΔT as a factor in the rate of heat loss is fairly obvious. No one would be surprised to learn that a house in Saskatoon would require a larger furnace to heat it than an equivalent house in Victoria since the indoor/outdoor temperature difference in the winter is much greater in Saskatoon.

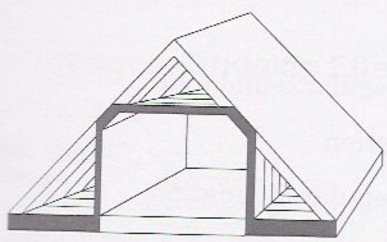
Area

The surface areas of floors, walls, ceilings, windows and doors are required to calculate heat loss. The interior dimensions of the building are used, since heat loss through these assemblies begins from the inside surface.

The important point to note here is that it is a building's interior surface area rather than its enclosed volume, which determines the conductive heat loss. This means, for example, that in insulating the roof of a storey-and-a-half house, insulating the rafters (A - Low Surface Area) would result in less heat loss than insulating the ceiling and knee walls (B - Low Volume) with the same thickness of insulation, even though the enclosed volume would be greater.



A Low Surface Area (less heat loss than B below)



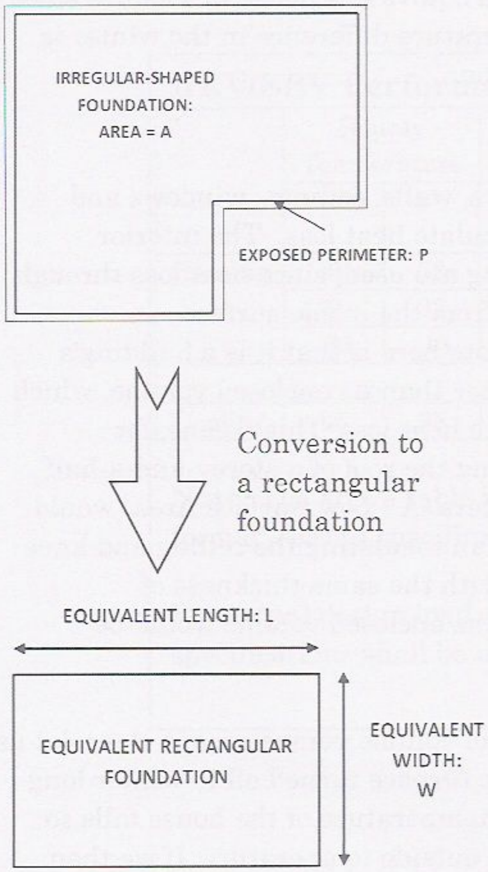
B Low Volume (more heat loss than A above)

To ensure that the issue of volume versus area is clear, let us consider a house with the furnace turned off in winter long enough that the interior temperature of the house falls so that it is the same as the outside temperature. If we then turn on the furnace, the amount of energy it will consume in bringing the house up to the thermostat setting temperature is related to the volume of the house – the more air there is to heat up, the more energy will be required to heat it.

However, once the air temperature is up to the thermostat setting, the furnace only has to replace the ongoing heat loss, which is dependent on the interior surface area, and not on the volume. As one seldom has to heat up a completely chilled house, the volume is therefore not a significant factor in heating calculations.

As part of the heat loss component for foundations (basement and slab-on-grade), foundation dimensions are required in order to utilize the Residential Foundation Thermal Load Calculator linked to the CSA F280-12 Standard. In some cases, foundations are not rectangular in shape and the area and perimeter shall be calculated first in order to obtain the equivalent length and width. Traditionally, these are based on external dimensions. However, for simplification, all area

and perimeter calculations will be based on **internal dimensions**.



For an irregular shaped basement or slab-on-grade foundation, to solve for the equivalent length, the formula is:

$$L = \frac{P + \sqrt{P^2 - 16A}}{4}$$

Where:

L = equivalent length of irregular foundation

P = perimeter of irregular foundation

A = area of irregular foundation

For an irregular shaped basement or slab-on-grade foundation, to solve for the equivalent width, the formula is:

$$W = \frac{A}{L}$$

Where:

L = equivalent length of irregular foundation

A = area of irregular foundation

W = equivalent width of irregular foundation

For some irregular shapes, this method might fail because $(P^2 - 16A)$ is negative. In such cases, replace $P^2 - 16A$ with zero. Then the external "Length" or "Width" would be approximately equal to:

$$L = \frac{P}{4}$$

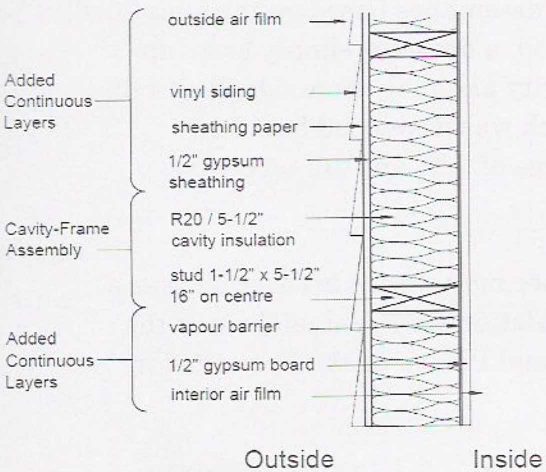
$$W = \frac{A}{L}$$

Thermal Resistance

The effectiveness of a material in resisting the flow of heat under static conditions is defined as its thermal resistance or R-value. For comparative purposes, the higher the resistance value of a material, the longer it will take for the heat to transfer through that material. For a building assembly such as a wall, the total thermal resistance is determined by adding the individual thermal resistances of its components.

An insulating material achieves high thermal resistance by interfering with convection and radiation, while presenting very little solid material to allow heat flow by conduction. The lighter and less solid the fibrous or cellular insulation material, the more effective it is, down to the point where it becomes too open textured and convection and radiation transfers begin to increase.

While all materials have some thermal resistance, those of most structural, cladding and finish materials are quite low. Thus, in the Canadian climate with current energy costs, all building assemblies making up the envelope of a building must incorporate sufficient insulation to approach a practical thermal resistance level.

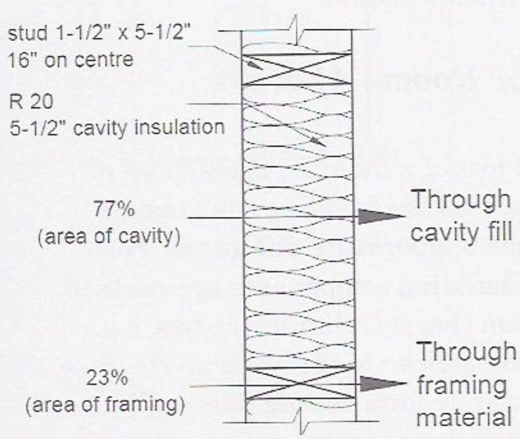


Thermal Bridging Effect in Building Envelope

A typical building envelope assembly (as shown on left) is comprised of two components: frame-cavity assembly (e.g. wood framed cavity filled with glass fibre batt insulation) and any continuous layers (e.g. exterior siding, interior finish, and any added layer of rigid insulation) that are added to the frame-cavity assembly.

In a frame-cavity assembly, heat can be conducted through two different paths: heat can be conducted via framing material, or it can also be conducted through cavity insulation.

Thermal-Bridging Effect



It is noted that heat tends to conduct through the path with the least thermal resistance, and since framing materials (e.g. wood) are poor insulation materials compared to other insulation materials, significant portion of heat may conduct via framing. This causes the overall change in effective R-value of cavity-framed assembly known as "thermal-bridging" effect.

Due to this thermal-bridging effect, effective R-value of a framed-assembly differs from its nominal R-value (e.g. 2 x 6, 16" o.c. wood-framed assembly with R20 nominal insulation has the effective R-value of 13.79), and a designer needs to employ a calculation method to obtain the effective R-value of framed assemblies.

Calculating Effective R-values for Envelope Assemblies

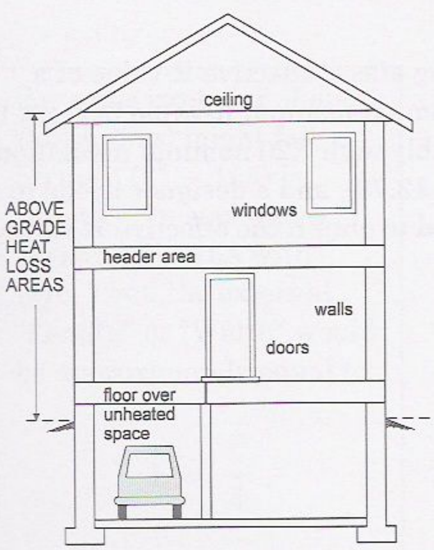
This manual provides three methodologies for calculating effective R-values for envelope assemblies, and they are all based on the Isothermal Planes Method.

Page A-1 to A-5 of Appendix A, "Instructions for Calculating Assembly R-Values", cover instructions for calculating R-value of building envelope assemblies based on the simplified methodology. In this method, a designer simply looks up effective R-values for a cavity assembly from a look-up table (Appendix A, Table 1) which was developed based on assumed framing percentage of 23% and 16" on centre spacing.

As an alternative, a designer may choose to carry out more detailed and accurate calculations of R-Value(s) using the full instructions of Isothermal Planes method provided in Appendix C.

During R-value calculation, a designer also needs to look up Appendix B, "Supplementary Information for Detailed R-value Calculations", which lists the R-value of different building materials for continuous layers.

Areas of Heat Loss for Rooms Above Foundation



The total above-grade heat loss of a building is made up of the sum of the losses through all the building components which see the indoor-outdoor temperature difference. For convenience of calculation, building components are parts of the shell which have common thermal characteristics, e.g. walls of uniform construction (brick veneer walls on the first floor would be treated separately form second floor walls covered with wood siding), windows, doors, ceilings, floors over unheated areas etc. The diagram to the left shows those areas of a house where heat is lost and/or where a heat loss calculation must be done. Each component will lose heat at a different rate and as a result, each building component must be looked at separately.

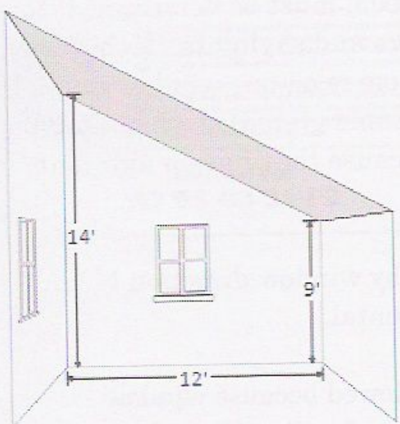
Sections 2.3 through to 2.10 deal specifically with each of the components of the above grade building envelope heat loss. Section 2.11 deals with the foundation heat loss which includes the below grade heat loss.

2.3 Gross Exposed Walls

- **Section 1, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

The gross exposed wall area is the total area of a wall including doors and windows. The heat loss of any portion of a wall that separates a conditioned space from an unconditioned space will have to be calculated. From the building plans or actual measurements of an existing house, one must determine the total area of these exposed walls.

The gross exposed wall area of a room equals the length of the exposed wall multiplied by its height. The length of wall is measured from inside surface of walls between conditioned and unconditioned spaces to the centerline of interior partition walls.



A room with a cathedral ceiling has various wall heights depending upon where the measurement is taken. As an example, assume the ceiling height ranges from 9 feet at its lowest point to 14 feet at its highest point. The average wall height then is (9 + 14) divided by 2 = 11.5 feet. To calculate the gross wall area you can use the length or width measurement and the average wall height. In the example then it would be 12 x 11.5 = 138 ft².

Remember that this average wall height applies only to the wall that has the varying height. In the example, the 'front' wall is 9 feet high and this is what would be used to calculate that wall area.

Structure Component Type

The column for "STRUCTURE" on the worksheet is used in cases where different construction types of the same component are found in a building such as a wall with brick veneer and another with stucco over rigid exterior insulation. Determine the number of wall construction types, and label each on a separate line, in the Structure column (ex. M for Main Floor, FW Foundation Wall etc), or the type of wall (S for stucco, B for brick etc). Often, the house designer will provide designations for all building components on the plans.

It is advised that the structure type label for each component should match the structure label that is already recorded previously under "Building Envelope Assemblies" in Section A, page 1 of the worksheet

HRAI Residential Heat Loss and Heat Gain Calculation:				
		HL ΔT =		HG ΔT =
COMPONENTS	STRUCTURE	EFFECTIVE R-VALUE Col 1	HL ΔT / R Col 2	SC Col 3
1.GROSS EXPOSED WALLS				
2.WINDOWS, GLASS DOORS AND SKYLIGHT				

Note: The use of the structure label applies to "STRUCTURE" in all sections, except Section 2, Windows, Patio Glass, Glass Doors and Skylights.

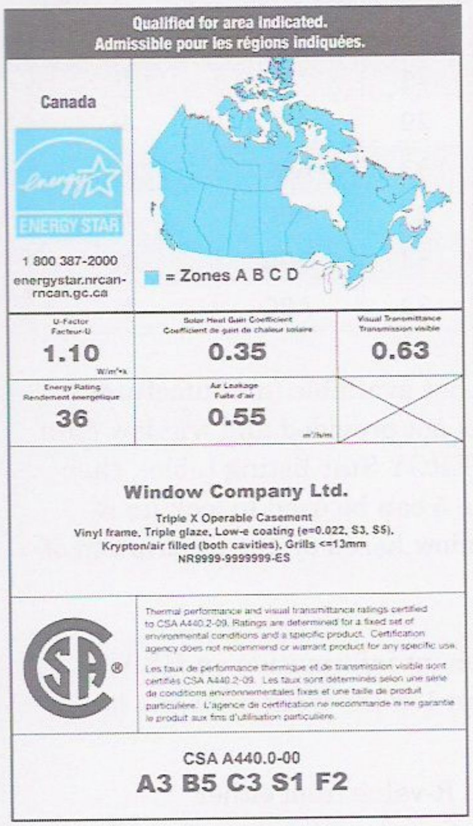
2.4 Windows, Glass Doors and Skylights

- **Section 2, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

For either windows or glass doors, the area calculated is based on the rough frame opening of the window or door. The total glass area in a given room must be determined; this includes glass areas in solid doors and skylights. If there are different types of glass in one room (e.g., one window is single glazed and the remainder are double glazed), each glass type will be identified as separate because they have a different rate of heat loss.

Structure designation would be by window direction N, S, E/W, NE/NW, SE/SW and Horizontal.

Note: The above procedure is followed because window directions will be required when performing Heat Gain calculations.



Glazing R-Value & Solar Heat Gain Coefficient (SHGC)

The most accurate and preferred method in obtaining R-value and Solar Heat Gain Coefficient is to look up the windows specification sheet provided by the windows manufacturer.

Windows usually come with a specification sheets which lists U-factor and Solar Heat Gain Coefficient (SHGC) value of the windows as shown left. From this specification sheet, one can simply look up the U-factor and SHGC for a window. Once U-factor of the window is looked up, then the RSI-value of the window is calculated as follows:

$$\text{RSI Value} = \frac{1}{\textbf{U Factor in SI unit}}$$

$$\text{R Value} = \frac{1}{\textbf{U Factor in Imperial unit}}$$

Example:

A window has a U-factor of 1.10 $W/(m^2 \cdot K)$ which is looked up from the specification sheet provided by the manufacturer. Calculate its R-value.

RSI-value = 1 ÷ U factor = 1 ÷ 1.10 = 0.909 $(m^2 \cdot K)$ / W

The RSI value above is in Metric. To convert that value Imperial units multiply the number by 5.678.

R-Value = 0.909 × 5.678 = **5.16 $(ft^2 \cdot °F)$/ (Btuh)**

If the window specification sheet from the manufacturer is not available, one can also choose to look up windows ENERGY Star listing table from the Natural Resources Canada (NRCan): Office of Energy Efficiency (OEE) website. This table provides specifications for windows based on the selected models and descriptions for windows as shown below.

Model	Brand	Product Name	U-factor (W/m² - K) ▲	Solar Heat Gain (SHGC)	Energy Rating	ENERGY STAR Zone(s)	ENERGY STAR Most Efficient 2014
XXXX-XXX	XX1	XX-XX1	1.7	0.49	29	ABC	N
XXXX-XXX	XX1	XX-XX1	1.7	0.4	24	A	N
XXXX-XXX	XX2	XX-XX2	1.7	0.49	29	ABC	N
XXXX-XXX	XX2	XX-XX2	1.7	0.55	33	ABC	N
XXXX-XXX	XX3	XX-XX3	1.7	0.55	33	ABC	N
XXXX-XXX	XX3	XX-XX3	1.7	0.55	33	ABC	N
XXXX-XXX	XX3	XX-XX3	1.7	0.54	32	ABC	N

If the above two options are not available (manufacturer's window specification sheet is not provided and window data is not listed on windows ENERGY Star listing table), then Appendix A, Table 2 to Table 5 can be used to look up R-value and SHGC for the window based on the description of windows assemblies.

To enter the windows component information on HRAI worksheet, Section 2, Column 1 of the worksheet can be completed as follows:

Step i) Obtain windows R-value from either manufacturer's specification sheet (most preferred), NRCan: Office of Energy Efficiency windows data table, or from Table 2 to Table 5 of Appendix A. Enter R-value on the designated line(s) within Section 2, Column 1, page 3 of the worksheet.

Calculate the Heat Loss Multiplier

The heat loss multiplier is defined as: $\frac{HL\ \Delta T}{R}$

Step i) Divide Heat Loss ΔT, (previously determined and recorded on top left-hand corner of the worksheet, page 3), by the applicable R-value noted Column 1, page 3 of the worksheet.

Step ii) Enter this amount(s) on the designated line(s) of Windows, Glass, Glass Doors and Skylights, Section 2, Column 2, page 3 of the worksheet.

The Heat Loss Multiplier will be the same for all windows of the same construction, regardless of the direction the window faces. Therefore, the R-Value and Heat Loss Multiplier from columns 1 and 2 above should be entered for each direction that windows face in the house.

Note: The previous procedures may be repeated to suit different types of glass where applicable. Once completed, enter as noted in Step ii) above.

2.5 Exposed Doors

- **Section 3, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

The area calculated is based on the rough frame opening of the door. The area of each door leading to the outside must be calculated. Glass areas in doors are calculated with windows and deducted from the area of the door. Do not include interior doors leading from conditioned space to conditioned space.

Other Exposed Doors R-Value

First, a designer needs to look up the applicable R-value for exposed doors from Table 6 in Appendix A. Then, Section 3 and Column 1, page 3 of the worksheet, "EXPOSED DOORS" can be completed as follows:

Step i) Look up Table 6 in Appendix A, select the applicable R-value, and enter it on the designated line(s) within Section 3, Column 1 of page 3 of the worksheet.

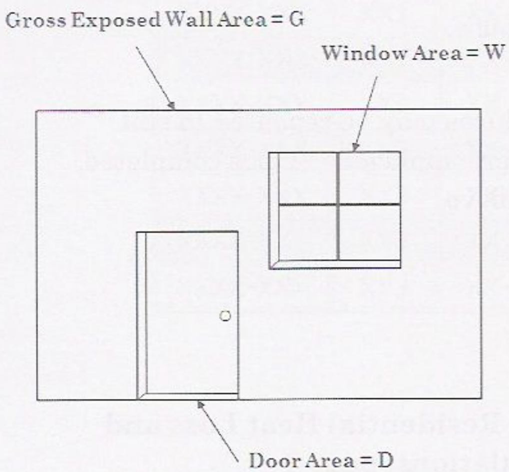
Calculate the Heat Loss Multiplier

The heat loss multiplier is defined as: $\dfrac{HL\ \Delta T}{R}$

Step i) Divide Heat Loss ΔT, (previously determined and recorded on top left-hand corner of page 3 of the worksheet), by the applicable R-value noted Column 1, page 3 of the worksheet.

Step ii) Enter this amount(s) on the designated line(s) of Other Exposed Doors, Section 3, Column 2, page 3 of the worksheet.

2.6 Net Exposed Walls



Net Exposed Wall Area
= G – W – D

- **Section 4, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Areas of each component of the building assembly are calculated separately. Therefore, the area of such components as windows and doors must be deducted from the Gross Wall Area resulting in the Net Wall Area.

Calculating Effective R-Value

From information established, together with instructions provided in Appendix A, on pages A-1 to A-5, "Instructions for Calculating Assembly R-Values", R-values of wood framed assemblies, insulated concrete forms (ICFs) or structural insulated panels (SIPs) can be calculated using Table 1 in Appendix A, and Appendix B as follows:

Step i) Determine the nominal (insulation only) R-value of the cavity insulation of any applicable framed assembly from building specifications or R-values listed in Appendix B

Step ii) Look up the effective R-value of the framed assembly from Appendix A, Table 1 based on the Nominal R-value found in Step i) and framing depth.

Step iii) Add R-value of any continuous layers to the result of Step ii) using the R-values from building specifications or R-value listed in Appendix B

As an alternative, a designer may choose to carry out a full detailed Isothermal Planes R-Value calculation method using the instructions provided in Appendix C.

After the effective R-value of the net exposed wall is calculated, it should be entered in Section 4, Column 1, page 3 of the worksheet.

Calculate the Heat Loss Multiplier

The heat loss multiplier is defined as: $\frac{HL\ \Delta T}{R}$

Step i) Divide Heat Loss ΔT, (previously determined and recorded on top left-hand corner of the worksheet, page 3), by the applicable R-value noted in Column 1, page 3 of the worksheet.

Step ii) Enter this amount(s) on the designated line(s) of Net Exposed Walls, Section 4, Column 2, page 3 of the worksheet

2.7 Header Areas

- **Section 5, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

> Header areas should be included as part of the room directly below the header area.

A Header is that section of the building where the floor joists meet the exterior wall. There will normally be a header area between the top of the concrete basement wall and the floor on the main level. If the house is a two storey, there will be a second header area between the ceiling of the main level and the floor of the second level.

When choosing the effective R-Value for the header from Appendix A, Table 1, use the R-Value for the "Headers" listed under 2" × 12" column.

When calculating the area of the Header, multiply the header height by the exposed length. When entering the Header Area on the worksheet, it will always be included as part of the room directly below it.

Header Areas R-Value

From information established, together with instructions in Appendix A, on pages A-1 to A-5, "Instructions for Calculating Assembly R-Values", determine the R-values of headers using the Table 1 in Appendix A, and Appendix B as follows:

Step i) Determine the nominal (insulation only) R-value of the cavity insulation of the building assembly from building specifications or R-values listed in Appendix B

Step ii) Look up the effective R-value of the assembly from Appendix A, Table 1 based on the Nominal R-value found in Step i), under "2 x 12" column.

Step iii) Add the R-value of any continuous layers to the result of Step ii) using the R-values listed in Appendix B

As an alternative, a designer may choose to carry out a full, detailed Isothermal Planes R-Value calculation using the instructions provided in Appendix C.

After the effective R-value of the header is calculated, it should be entered in Section 5, Column 1, page 3 of the worksheet.

Calculate the Heat Loss Multiplier

The heat loss multiplier is defined as: $\frac{HL\ \Delta T}{R}$

Step i) Divide Heat Loss ΔT, (previously determined, top left-hand corner of page 3 of the worksheet), by the applicable R-value noted in Column 1, page 3 of the worksheet.

Step ii) Enter amount(s) on the designated line(s) of Header Areas, Section 5, Column 2, page 3 of the worksheet.

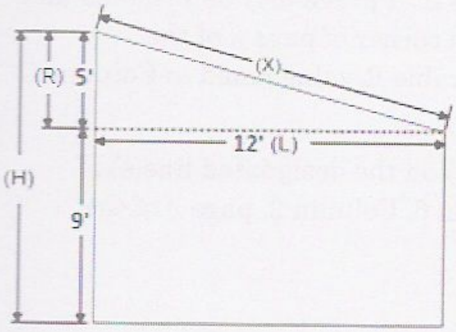
2.8 Exposed Ceilings

- **Section 6, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

The area of a normal ceiling is usually its length times its width (L x W). Areas of sloped or cathedral ceilings are calculated for the actual sloped section. Knee walls, which are exposed to similar conditions as ceilings are included with the ceiling area. Similar to walls containing windows, the net exposed area of ceilings is calculated if skylights or other openings are present.

Cathedral Ceilings

To more accurately determine the area of a cathedral ceiling one must first determine the length of the sloped ceiling.



To solve for x the equation is:

$$x = \sqrt{(\text{Length})^2 + (\text{Rise})^2} = \sqrt{L^2 + R^2}$$

$$x = \sqrt{12^2 + 5^2} = \sqrt{144 + 25} = \sqrt{169} = 13$$

Therefore, the length of the ceiling is 13 feet. The width of the room is 15 feet. The area of the ceiling is easily determined by multiplying length x width or 13 x 15 = 195 sq ft.

Ceiling R-Value

From information established, together with instructions in Appendix A, on pages A-1 to A-5, "Instructions for Calculating Assembly R-Values", determine the R-values of ceilings from the Table 1 in Appendix A, and Appendix B as follows:

Step i) Determine the nominal (insulation only) R-value of the cavity insulation of the building assembly from building specifications or R-values listed Appendix B

Step ii) Look up the effective R-value of the assembly from Appendix A, Table 1 based on the Nominal R-value found in Step i) and framing depth.

Step iii) Add the R-value of any continuous layers to the result of Step ii) using the R-values from the building specifications or R-values listed in Appendix B

As an alternative, a designer may choose to carry out a full, detailed Isothermal Planes R-Value(s) calculation method using the instructions provided in Appendix C.

After the effective R-value of the exposed ceiling is calculated, it should be entered in Section 6, Column 1, page 3 of the worksheet.

Calculate the Heat Loss Multiplier

The heat loss multiplier is defined as: $\frac{HL\ \Delta T}{R}$

Step i) Divide Heat Loss ΔT,(previously determined and recorded on top left-hand corner of page 3 of the worksheet), by the applicable R-value noted in Column 1, page 3 of the worksheet.

Step ii) Enter amount(s) on the designated line(s) of Exposed Ceilings, Section 6, Column 2, page 3 of the worksheet.

2.9 Exposed Floors

- **Section 7, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Heat Loss calculations are required for Exposed Floors only in cases where the floor in a given room is exposed to outside or unconditioned spaces below.

Exposed Floor R-Value

From information established, together with instructions in Appendix A, on pages A-1 to A-5, "Instructions for Calculating Assembly R-Values", determine the R-values of exposed floors from the Table 1 in Appendix A, and Appendix B as follows:

Step i) Determine the nominal (insulation only) R-value of the cavity insulation of the building assembly from the building specifications or the R-values listed in Appendix B

Step ii) Look up the effective R-value of the assembly from Appendix A, Table 1 based on the Nominal R-value found in Step i) and framing depth.

Step iii) Add the R-value of any continuous layers to the result of Step ii) using the R-values from building specifications or R-values listed in Appendix B

As an alternative, a designer may choose to carry out a full, detailed Isothermal Planes R-Value(s) calculation method using the instructions provided in Appendix C.

After the effective R-value of the exposed floor is calculated, it should be entered in Section 7, Colum 1, page 3, of the worksheet.

Calculate the Heat Loss Multiplier

The heat loss multiplier is defined as: $\frac{\mathbf{HL\Delta T}}{\mathbf{R}}$

Step i) Divide Heat Loss ΔT, (previously determined and recorded on top left-hand corner of page 3 of the worksheet), by the applicable R-value noted in Column 1, page 3 of the worksheet.

Step ii) Enter the amount(s) on the designated line(s) of Exposed Floors, Section 7, Column 2, page 3 of the worksheet.

2.10 Other

- **Section 8, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Section 8 provides extra space as required for unusual circumstances. An example would be when a particular house had 3 types of doors. As there are only 2 lines provided in Section 3 (Exposed Doors), the 3rd door could be recorded in Section 8.

2.11 Foundation Conductive Heat Loss

- **Section 9, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

One of the largest contributors to heat loss in Canadian housing - and the unrecognized one - has been the common basement or cellar. Three misconceptions have obscured this costly reality: first, that an "unheated" basement is indeed unheated and therefore can scarcely throw away much heat; second, that the earth surrounding and underlying the foundation itself acts as a good insulator; and third, that heat "rises" and therefore is not lost downward.

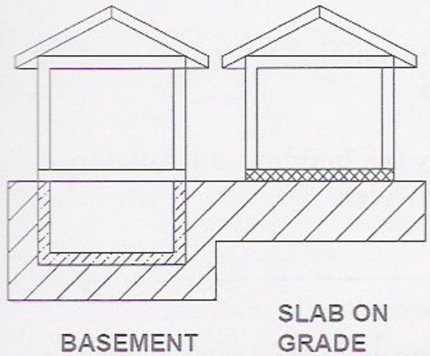
Any basement or cellar receives large quantities of heat, both from the floor above and from the furnace and ducting (or boiler and piping). In cases where heat outlets are built into the basement, considerably more heat is contributed, but even without these, a basement or cellar does qualify as a heated space.

Even when the dwelling has only 12 to 16 inches of basement wall protruding, the heat loss through that uninsulated above-grade portion alone (for 8" concrete plus outside and inside air films, the R-Value is 1.314) can be almost the largest single amount lost from the whole building, given that the superstructure is well insulated. Further losses occur through below-grade construction and through air leakage into and out of the basement.

Below-grade, the heat loss for the first 12 - 24 inches down from the surface may be half as large as that from the above-grade basement wall. Deeper yet, the insulating effect of the earth improves, but not to the extent that has been assumed in the past. Heat transfer through the earth up to the atmosphere and down to the water table is an extremely variable, complex phenomenon. Heat transfer is affected not only by the atmospheric climate the house is located in and by the amount of insulation on the basement walls and floor, but also by the soil temperature, the thermal conductivity of the soil and the depth of the water table. The method of calculating foundation heat loss described in the CSA F280-12 standard is based on research conducted by the National

Research Council of Canada and additional work done by Natural Resources Canada.

CSA F280-12 includes a link to Microsoft Excel® spreadsheets for calculating the heat loss associated with all types of common foundations. These linked spreadsheets now require designers to use a computer-generated solution. Since heat losses from foundations contribute significantly to residential heating requirements (as much as 25% of the total heating load for buildings), there is a definite need for accurate foundation heat loss calculations as provided by the spreadsheet algorithms linked with the standard.



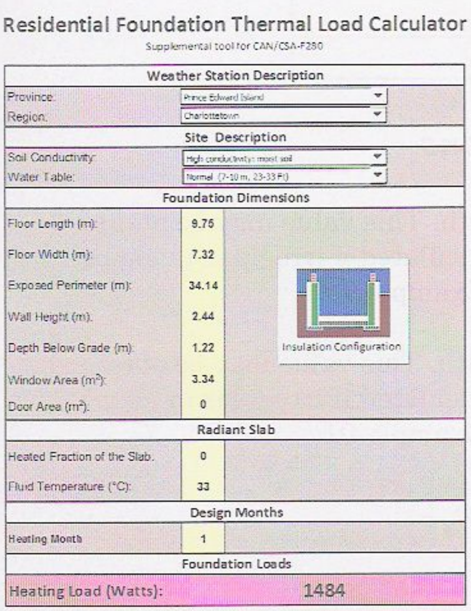
It is important to note that the heat loss from the above grade portion of basement walls is accounted for in the foundation heat loss model (BasementHLR.xls). Therefore, it is not necessary to calculate the heat loss for the above grade portion of the basement walls.

Two Microsoft Excel® spreadsheets have been provided to automate the calculation procedures for basement and slab-on-grade foundations and are as follows:

a) BasementHLR.xls - This spreadsheet is referred to as the **Residential Foundation Thermal Load Calculator** and shall be used to calculate heat loss rate for basements

b) SlabOnGradeHLR.xls - This spreadsheet is referred to as the **Residential Slab on Grade Thermal Load Calculator** and shall be used to calculate the heat loss rate for slab-on-grade foundations

Note: The Calculators are only available in Metric. The Designer must convert all geometry and R value information to metric before entering it into the Spreadsheets.



Residential Foundation Thermal Load Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description	
Province:	Prince Edward Island
Region:	Charlottetown
Site Description	
Soil Conductivity:	High conductivity: moist soil
Water Table:	Normal (7-10 m, 23-33 Ft)
Foundation Dimensions	
Floor Length (m):	9.75
Floor Width (m):	7.32
Exposed Perimeter (m):	34.14
Wall Height (m):	2.44
Depth Below Grade (m):	1.22
Window Area (m²):	3.34
Door Area (m²):	0
Radiant Slab	
Heated Fraction of the Slab:	0
Fluid Temperature (°C):	33
Design Months	
Heating Month	1
Foundation Loads	
Heating Load (Watts):	1484

Insulation Configuration

Residential Foundation Thermal Load Calculator (BasementHLR.xls)

Foundation conductive heat loss may be calculated collectively when treated as a single room. Heat loss for each room in the foundation can then be calculated based on its exposed perimeter.

The BasementHLR.xls spreadsheet which contains the **Residential Foundation Thermal Load Calculator** calculates the total perimeter based on internal length and width inputs. The total foundation heat loss (heat load in Watts) as per the output of the spreadsheet is then multiplied by the exposed perimeter fraction for each room in order to obtain individual room heat loss.

Based on the information provided about the foundation, the heat loss for the foundation (basement) may be completed by entering the inputs into the spreadsheet

Weather Station Description

Step i) Select the Province the building is located in using the drop down menu provided.

Step ii) Select a region or city the building is located in using the drop down menu provided.

Site Description

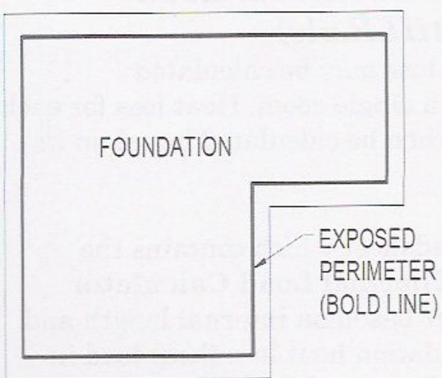
Step iii) Select the appropriate soil conductivity from the drop down menu as provided in the design conditions. Three types of soil conductivity are available:

Type of Soil	Conductivity (W/m/C)
Normal	0.85
High	1.275
Very Wet	1.9

Step iv) Select the water table from the drop down menu as provided in the design conditions. Three types of water table are available:

Level	Depth (Meters)
Shallow	5
Normal	8
Deep	12

Foundation Dimensions



Step v) Input the floor length. This value may be obtained from the building plan or calculated if irregular in shape. This is 9.75 m (= 32 ft) for Example-01.

Step vi) Input the floor width. This value may be obtained from the building plan or calculated if irregular in shape. This is 7.32 m (= 24 ft) for Example-01.

Note A: As mentioned previously in the area calculation section of the manual, for irregular shaped (non-rectangular shape) foundation, use the following formula to calculate the equivalent length and width, and use them in the basement & slab-on-grade thermal load calculator.

For an irregular shaped basement or slab-on-grade foundation, to solve for the equivalent length, the formula is:

$$L = \frac{P + \sqrt{P^2 - 16A}}{4}$$

Where:

L = length

P = perimeter of irregular foundation

A = area of irregular foundation

For an irregular shaped basement or slab-on-grade foundation, to solve for the equivalent width, the formula is:

$$W = \frac{A}{L}$$

Where:

L = length

A = area of irregular foundation

W = equivalent width of irregular foundation

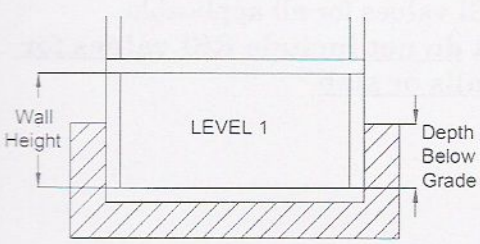
For some irregular shapes, this method might fail because ($P^2 - 16A$) is negative. In such cases, replace $P^2 - 16A$ with zero. Then the external "Length" or "Width" would be approximately equal to:

$$L = \frac{P}{4}$$

$$W = \frac{A}{L}$$

Step vii) Input the exposed perimeter. This value for the exposed perimeter is for the foundation. This is 34.14 m (= 112 ft) for Example-01

Note B: When the exposed perimeter is left at zero, the **BasementHLR.xls** spreadsheet automatically calculates the exposed perimeter as twice the sum of floor length and width. This is the correct exposed perimeter for a detached, rectangular-shaped foundation.

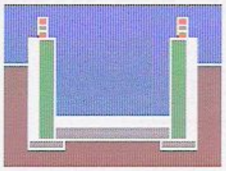


Step viii) Input the value for the wall height. This is the internal ceiling height measured from the top of the floor slab to the ceiling level. This value is provided in the foundation floor plan. This is 2.44 m (= 8 ft) for Example-01.

Step ix) Input the depth below grade. This value is measured from the grade level to the top of the floor slab. This value is provided in the foundation floor plan. This is 1.22 m (= 4 ft) for Example-01.

Step x) Enter the window area. This is the sum of all window areas in the foundation level. This is 3.34 m² (= 36 ft²) for Example-01.

Step xi) Enter the door area. This is the sum of all door areas in the foundation level. This is 0 m² (= 0 ft²) for Example-01.



Insulation Configuration

Step xii) Click on the Insulation Configuration button to view further foundation construction details. A snapshot of this button is provided on left, and configuration contains the following selection options:

Construction

Select the construction type based on the design information provided. The options are: concrete, wood and concrete & wood.

Insulation Placement

Select the insulation placement based on the design information provided.

Note A: If slab insulation is present, the location must be selected from the list provided. This additional list is only viewable if a foundation type containing slab insulation is selected from the Insulation options.

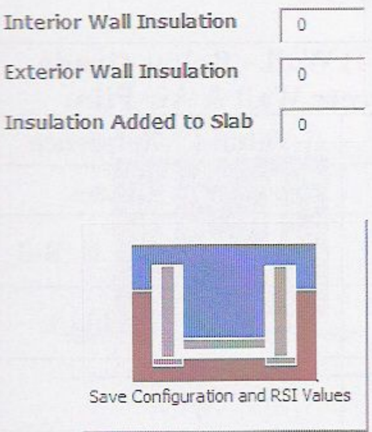
Foundation Code

Once you have selected the Construction and Insulation Placement, a subset of foundation types is made available. Select the most appropriate foundation code (e.g. BCCA_4, BCCA_1...etc) based on the descriptions in the Calculator compared to the design information provided.

Insulation RSI Values

Input the appropriate RSI-values for all insulation configurations as per the design information provided. When calculating insulation RSI values for the foundation thermal load calculator, include RSI values for all applicable assemblies and layers, but **<u>do not include RSI values for air films, foundation walls or slab</u>**.

In general, the following materials would be considered when calculating added insulation RSI values for the foundation thermal load calculator



Instructions for Calculating RSI Insulation Values for Basement Thermal Load Calculator	
RSI Insulation Value for:	**Include (if applicable) RSI values for:**
Interior Wall Insulation	- frame-cavity assembly on interior side of the wall - added rigid insulation layer on interior side of the wall - interior finish (e.g. gypsum)
Exterior Wall Insulation	- rigid insulation layer added on exterior side of the wall
Added Insulation Above Slab	- floor finish (e.g. carpet) - sheathing - added rigid insulation layer added above slab - frame-cavity assembly added above slab
Added Insulation Below Slab	- rigid insulation layer added below slab
Note: When calculating RSI insulation values for the basement thermal load calculator, <u>**do not include RSI values for air films, foundation walls or slab**</u>	

Note B: When the insulation RSI values for the wall or slab are calculated to be less than 0.04 RSI (= 0.23 R), then use uninsulated configuration for the foundation wall or slab. (When a user inputs a very small number for insulation RSI values, the calculator will not work properly and will give numerical errors)

Example-01:

For Exampe-01, insulation is applied to the interior of the foundation wall. The insulation RSI values for foundation wall and slab are calculated as follows:

Structure	Foundation (Level 1) Wall – Below Grade - Excluding Concrete Wall & Air Film		
Layer		R-Value	Reference
8" concrete (150 lb/ft³) (= 8 × 0.058)		Excl.	Excl.
Interior Side of Concrete Wall	3" extruded polystyrene (XPS) (Type 4)	15.15	App. B, B-3
	1" × 4" strapping applied w/o cavity insulation	1.14	Table 1
	Polyethylene vapour barrier	-	-
	1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)		Excl.	Excl.
R-VALUE ON INTERIOR SIDE OF CONCRETE WALL		16.73	
RSI-VALUE = R-Value × 0.1761		2.95	

It is noted that the interior side of the wall is adequately insulated (>0.23 R or 0.04 RSI). Therefore, the configuration for the interior wall insulation should be used in the thermal load calculator.

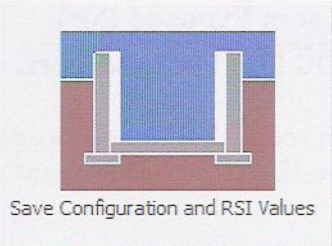
Structure	Foundation (Level 1) Slab on Grade Floor (Uninsulated) – Excluding Concrete Slab & Air Film	
Layer	R-Value	Reference
Interior air film - floors	Excl.	Excl.
Linoleum tile	0.05	App. B, B-5
4" concrete slab (150 lb/ft³)	Excl.	Excl.
R-VALUE ABOVE CONCRETE SLAB	0.05	Uninsulated

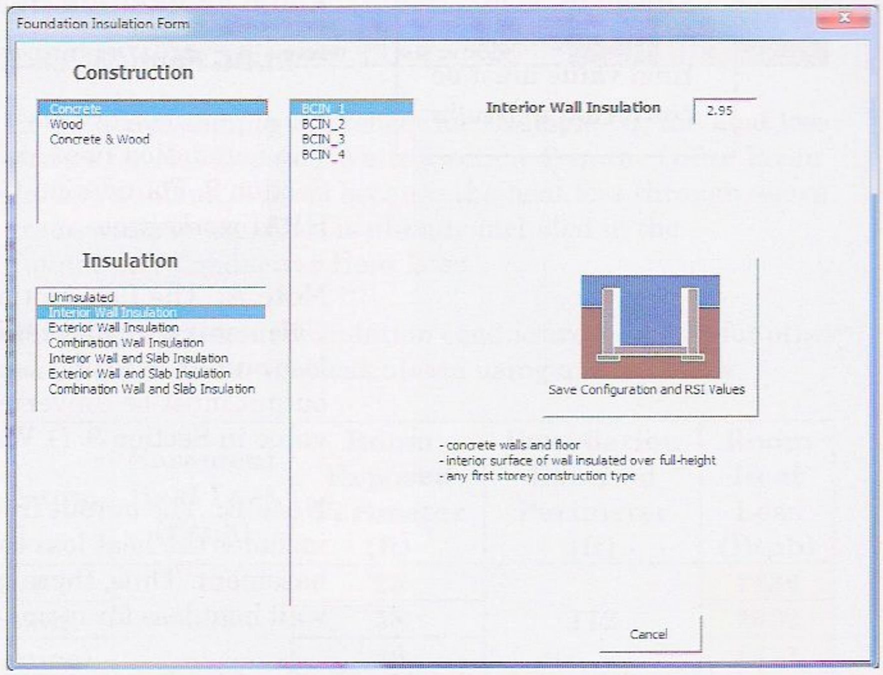
It is noted that the RSI-value for the slab is very small (<0.23 R or 0.04 RSI) and negligible. Thus, uninsulated configuration for the slab should be used in the thermal load calculator.

Basement Foundation Configuration for Example-01:
Configuration for concrete wall & floor construction with interior wall insulation & no slab insulation **(BCIN_1)** will be used, with interior wall RSI insulation value of 2.95

Note A: Users must select the Save Configuration and RSI Values button as shown on left side in order to retain the selected information. Otherwise, the final heat loss output will not match the specified configurations.

Note B: A description and image is provided for each foundation code as shown below.





Radiant Slab

Step xiii) Input the Heated Fraction of the Slab. This is the ratio of the heated slab area to the total slab area.

Step xiv) Input the Fluid Temperature. This is the average fluid temperature for in- floor radiant hydronic heating systems. For electric in-floor radiant heating, this is the average surface temperature of the electric cable.

Design Months

Step xv) This field cannot be changed. It represents the month of January which is the design month for heating load.

Foundation Thermal Loads - Rooms

The final output of the Residential Foundation Thermal Load Calculator is in Watts (SI). The final value must be converted to Btu/hr.

Step xvi) This is the final output of heat loss for the foundation, which should be apportioned to each room in the foundation based on exposed perimeter ratio using the following formula:

Room Foundation Heat Loss

$$= \textbf{BLDG Foundation HL} \times \frac{\textbf{Room Exposed Peri.}}{\textbf{BLDG Fdn Exposed Peri.}}$$

The foundation heat loss for each room should be recorded in Section 9, Foundation Conductive Heat Loss, Basement on HRAI worksheet.

Note A: The Residential Foundation Thermal Load Calculator spreadsheet is in metric. As such, the final heat loss output (Heating Load) is expressed in Watts. The final output must be converted to Btu/hr before recording the value in Section 9. (1 Watt = 3.412 Btu/h)

Note B: The output from BasementHLR.xls spreadsheet includes the heat loss through the above grade walls in the basement. Thus, there is no need to calculate above grade wall heat loss for rooms in basement level.

Example-01:

In Example-01, the BasementHLR.xls spreadsheet gives the final output for basement foundation heat loss as 1484 W, which is equal to:

1484 W × 3.412 = **5063 Btuh** (building foundation loss)

To calculate the foundation conductive heat loss for the Office Room (OFF) in the basement, the foundation conductive heat loss needs to be apportioned based on exposed perimeter ratio:

Building Foundation Exposed Perimeter = 112 ft (= 34.14 m)

Office (OFF) Exposed Perimeter = 25 ft (= 7.62 m)

Foundation conductive heat loss for Office (OFF)
= 5063 Btuh × 25 ft / 112 ft = **1130 Btuh**

HRAI Residential Heat Loss and Heat Gain Calculations						Page 3 of ___			
		HL ΔT =	76	HG ΔT =					
COMPONENTS	STRUCTURE	EFFECTIVE R-VALUE Col 1	HLΔT / R Col 2	SC Col 3	(HGΔT+SC) / R Col 4	P_E 25	LVL 1		
						H 8	RM OFF		
						A_F 150 Area		HEAT LOSS	HEAT GAIN
4.NET EXPOSED WALLS	MFW	16.13	4.71					Do not calculate for basement	
	FW	18.14	4.19			92.00			
9.FOUNDATION CONDUCTIVE HEAT LOSS		☑ BASEMENT	☐ SLAB ON GRADE					1130	

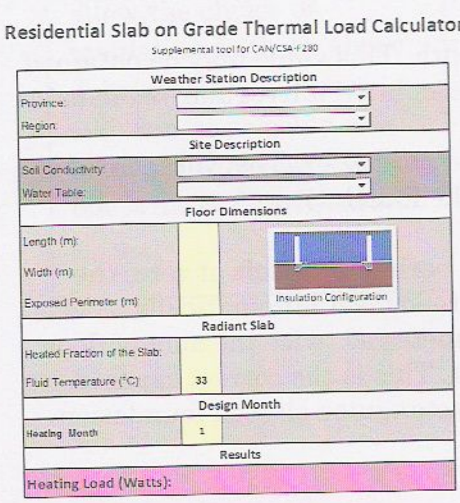
In the above sample worksheet for Example-01, the heat loss entries for Net Exposed Walls (Section 4) in the Office Room are left at blank. This is because the heat loss through above grade walls in the office is already included in the Foundation Conductive Heat Loss.

Similarly, basement foundation conductive heat loss for other basement rooms can be calculated using a table below:

Room Name	Basement Heat Loss (Btuh)	Room Exposed Perimeter (ft)	Foundation Exposed Perimeter (ft)	Room Heat Loss (Btuh)
Office	5063	25	112	1130
Rec room		58		2622
Mechanical		29		1311

The foundation heat loss calculated for each room should be recorded in Section 9, Foundation Conductive Heat Loss, Basement on HRAI worksheet.

Residential Slab on Grade Thermal Load Calculator (SlabOnGradeHLR.xls)



For rooms or spaces with floors on soil at the level of the exterior grade, the conductive heat loss shall be calculated as the sum of the heat loss of all the building components separating the room from the outside. The **SlabOnGradeHLR.xls** spreadsheet, which contains the **Residential Slab on Grade Thermal Load Calculator**, is used to calculate the heat loss for the foundation (Slab-on-grade).

Based on the information provided about the slab- on- grade building, the heat loss for the slab-on-grade level may be completed by entering inputs into the spreadsheet shown on left side of this page.

Weather Station Description

Step i) Select the Province the building is located in using the drop down menu provided.

Step ii) Select a region or city the building is located in using the drop down menu provided.

Site Description

Step iii) Select the appropriate soil conductivity from the drop down menu as provided in the design conditions. Three types of soil conductivity are available:

Type of Soil	Conductivity (W/m/C)
Normal	0.85
High	1.275
Very Wet	1.9

Step iv) Select the water table from the drop down menu as provided in the design conditions. Three types of water table are available:

Level	Depth (Meters)
Shallow	5
Normal	8
Deep	12

Foundation Dimensions

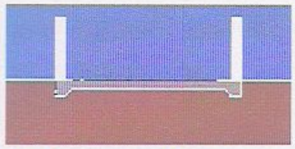
Step v) Input the floor length. This value may be obtained from the building plan or calculated if irregular in shape.

Step vi) Input the floor width. This value may be obtained from the building plan or calculated if irregular in shape.

Step vii) Input the exposed perimeter. This value is for the real exposed perimeter of the foundation.

Note A: When the exposed perimeter is left at zero, the **SlabOnGradeHLR.xls** spreadsheet automatically calculates the exposed perimeter as twice the sum of floor length and width by default. This is the correct exposed perimeter for a detached, rectangular-shaped foundation.

Insulation Configuration



Insulation Configuration

Step viii) Click on the Insulation Configuration button to view further slab on grade construction details. A snapshot of this button is shown on the left, and the configuration contains the following selection options:

Insulation
Select the insulation placement based on the design information provided.

Note A: If Below Slab is selected, further slab insulation information must be selected from the **Coverage** list. This additional list is only viewable if Below Slab is selected from the Insulation options.

> Skirt Insulation is insulation that extends down the outside edge of the slab or at any angle out from the edge of the slab, including horizontal just below grade.

Skirt
Select whether a skirt is present.

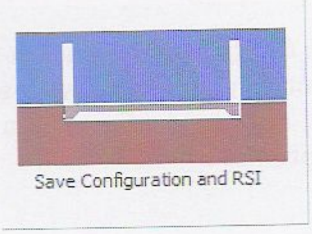
Coverage
Only applies if Below Slab is selected. See Note A.

Foundation Code
Select the appropriate foundation code (e.g. SCB_2, SCB_5...etc) based on the design information provided.

Insulation RSI Values
Input the appropriate RSI-values for all insulation configurations as per the design information provided. Include RSI values for all applicable assemblies and layers, but do not include RSI values for air films and concrete slab.

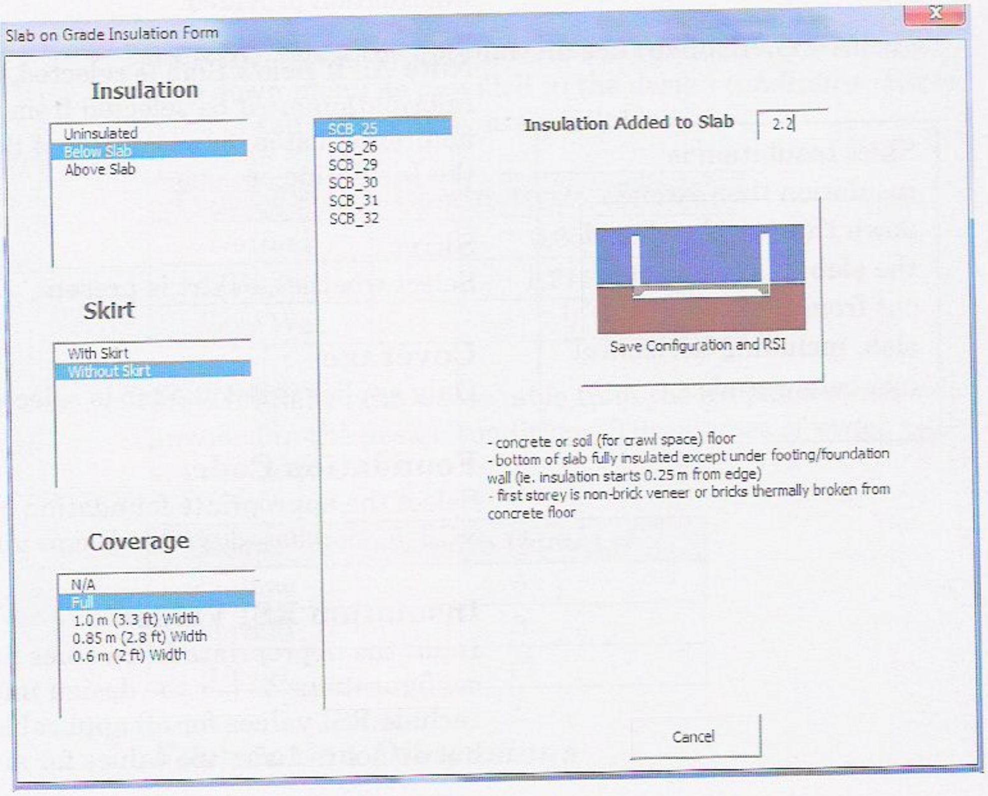
> The calculator does not allow the choice of insulation for both above & below slab (only one side can be selected at a time). In this case, choose one with higher R-value.

Instructions for Calculating RSI Insulation Values for Basement Thermal Load Calculator	
RSI Insulation Value for:	**Include (if applicable) RSI values for:**
Added Insulation Above Slab	- floor finish (e.g. carpet) - sheathing - added rigid insulation above slab - frame-cavity assembly above slab
Added Insulation Below Slab	- rigid insulation added below slab
Skirt Insulation (For uninsulated slabs with skirt)	- skirt insulation
Note: When calculating RSI insulation values for the slab-on-grade thermal load calculator, **do not include RSI values for air films and concrete slab**	



Note A: Users must select the Save Configuration and RSI Values button as per the image shown on left in order to retain the selected information. Otherwise, the final heat loss output will not match the specified configurations.

Note B: A description and image is provided for each foundation code as shown below.



Radiant Slab

Step ix) Input the Heated Fraction of the Slab. This is the ratio of heated slab area to the total slab area.

Step x) Input the Fluid Temperature. This is the average fluid temperature for in floor radiant hydronic heating systems. For electric in-floor radiant heating, this is the average surface temperature of the electric cable.

Design Months

Step xi) This field cannot be changed. It represents the month of January which is typically the coldest month of the year.

Foundation Thermal Loads

> The final output of the Residential Slab on Grade Thermal Load Calculator is in Watts (SI). The final value must be converted to Btu/hr.

Step xii) This is the final output of heat loss for the foundation, which should be apportioned to each room in the foundation based on exposed perimeter ratio using the following formula:

$$\textbf{Room Foundation Heat Loss} = \textbf{BLDG Foundation HL} \times \frac{\textbf{Room Exposed Peri.}}{\textbf{BLDG Fdn Exposed Peri.}}$$

The foundation heat loss for each room should be recorded in Section 9, Foundation Conductive Heat Loss, Slab On Grade.

Note A: The Residential Foundation Thermal Load Calculator spreadsheet is in metric. As such, the final heat loss output (Heating Load) is expressed in Watts. The final output must be converted to Btu/hr before recording the value in Section 9. (1 Watt = 3.412 Btu/h)

2.12 Room Section of Worksheet

Page 3 of ____			
P_E		LVL	
H		RM	
A_F		HEAT	HEAT
Area		LOSS	GAIN

At the top of each Room section, enter the name of the room, building level (LVL) in which the room is located, and its Exposed perimeter (P_E), height (H) and the floor area (A_F).

1. Exposed perimeter (P_E) is the perimeter which separates a room (conditioned space) and unconditioned spaces.

2. Height (H) of a room is the ceiling height for the room without including the header height. (e.g. for basement with 8 ft ceiling height and 1 ft header above basement wall, then basement height is entered as 8 ft after excluding the header height)

3. The floor area (A_F) is the area of the room based on interior dimensions.

For each room, there are three columns on the worksheet.

Step i) In the first column, enter the gross area of each component (gross exposed wall area, window area, etc.).

Note A: Net Exposed Wall (Section 4) can be calculated by subtracting window and door areas from the Gross Exposed Wall Areas.

Step ii) In the second column, enter the Heat Loss. The Heat Loss is calculated by multiplying the area of the component (Area Column) in the room by the heat loss multiplier (Column 2, page 3 of the worksheet) for that component.

$$\textbf{Heat Loss} = \textbf{Heat Loss Multiplier (Col. 2)} \times \textbf{Area}$$

Note B: Column 3 & 4 are not used for heat loss calculations.

Note C: Each room in which a separate heating duct would be required must be calculated separately. The area of an inside hallway, stairway or closet where a separate heating duct would not be provided, must be included in the adjacent room(s).

2.13 Total Conductive Heat Loss

- **Section 10, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add heat loss amounts from Sections 2 to 9, for each room on a particular level.

> **Note A:** This Section 2.13 must be completed before proceeding to next sections of the worksheet.

Total Level Conductive Heat Loss (Section 10) is the sum of all room conductive heat losses (Section 10, each Room) for a level. Calculate the Total Level Conductive Heat Loss for each level, and enter this amount in the space provided on the left side of Section 10, page 3 of the worksheet under applicable level (LVL 1, LVL 2, LVL 3 or LVL 4).

For Example-01:

Total conductive heat loss for Level 1
= 1748 + 3885 + 2210 = **7843 Btuh**

Total conductive heat loss for Level 2
= 3434 + 3607 + 4485 + 4561 = **16087 Btuh**

		LVL 1	LVL 2	LVL 3	LVL 4
10. TOTAL	TOTAL HEAT LOSS	7843	16087		
CONDUCTIVE	TOTAL HEAT GAIN				

2.14 Air Change Heat Loss

In any building there is going to be a certain amount of air leaking across the building envelope. This air must be accounted for when doing a calculation as it is warm air being lost and replaced by cooler outside air which has to be heated.

Air Change

Air change is the continuous exchange of air between every building and the outdoors. The air change is the result of two separate processes: *ventilation* and *air leakage*.

Ventilation

Ventilation is a controlled air change. It can be provided by bathroom and kitchen exhaust fans, HRV/ERV, clothes dryer and any other mechanical devices that expel air from, or deliver air into the structure.

Air Leakage

Air leakage is an uncontrolled air change, and includes both *infiltration* and *exfiltration*, as air flows through cracks, structural joints, gaps around window frames, and many other unintentional openings in the building envelope. *Infiltration* refers to the flow of air from the outdoors into the building enclosure. *Exfiltration* refers to the flow of air from inside of the building to the outdoors.

Air Leakage Heat Loss Calculations are completed in three steps:

- **Step i)** Calculation of Building Air Leakage Heat Loss
- **Step ii)** Calculation of the Air Leakage Heat Loss Multipliers
- **Step iii)** Calculation of Air Leakage Heat Loss for each room

Note: Space and formulas have been placed on the "Formula Sheet (For Air Leakage / Ventilation Calculation)" for calculating the Building Ventilation Heat Loss and Air Leakage Heat Loss Multipliers

A significant change to the 2012 edition of the CSA F280 Standard are the inclusion of a link to a Microsoft Excel® spreadsheet that calculates the envelope air leakage rate as part of the heat loss due to air leakage.

Note A: Use of the AIM2.xls spreadsheet is required in order to complete Step i). The output from the spreadsheet is the envelope air leakage rate for heating which is required in the formula to calculate the Heat Loss Due to Air Leakage for the building.

1) Calculation of Heat Loss Due to Air Leakage

The calculation of the heat loss due to air leakage is calculated separately from the heat loss due to mechanical ventilation.

The equation for air leakage heat loss for the building is:

$$\mathbf{HL_{leak} = B \times LR_{airh} \times V_b \times HL\Delta T}$$

where:

$\mathbf{HL_{leak}}$ = building air leakage heat loss

B = use 0.018 (Imperial) **OR** 0.33 (Metric)

$\mathbf{LR_{airh}}$ = envelope air leakage rate for heating (output from the Envelop Air Leakage Calculator spreadsheet)

$\mathbf{V_b}$ = building volume, ft^3 from section B page 2.

HLΔT = heat loss ΔT from top left corner on page 3 of the worksheet

Note:
It is important to note that the term "air change" refers to the sum of "air leakage" and "ventilation".
The term "air leakage" refers to uncontrolled air exchange across the building envelope.

The calculation of the design temperature difference, HLΔT, has already been covered earlier in this chapter, and the total volume of the building is already determined and entered in Section B, page 2 of the worksheet. CSA F280-12 includes a link to a Microsoft Excel® spreadsheet (AIM2.xls) that is used to calculate the envelope air leakage rate. This output is used to calculate the Building Air Leakage Heat Loss. Designers shall access the spreadsheet and enter the appropriate dimensional data, environmental data, and ventilation configurations for the building. The spreadsheet, titled **Envelope Air Leakage Calculator** precludes the use of a manual calculation and is a mandatory part of the calculation.

There are two steps in the process of calculating Building Air Leakage Heat Loss:

Step i) Use the Envelope Air Leakage Calculator to obtain the envelope air leakage rate for heating (LR_{airh})

Step ii) Insert the envelope air leakage rate determined in Step i) into the formula for Building Air Leakage Heat Loss (HL_{leak}) provided on the Formula sheet to calculate Building Air Leakage Heat Loss (HL_{leak}).

Envelope Air Leakage Calculator

Obtaining the Envelope Air Leakage Rate by using the Envelope Air Leakage Calculator spreadsheet is completed in the following steps:

Weather Station Description

Step i) Select the province the building is located in using the drop down menu. For Example-01, this is Prince Edward Island.

Step ii) Select the Region (City) the building is located in using the drop down menu. For Example-01, this is Charlottetown.

Step iii) By default, the Weather Station location is always "Open flat terrain, grass, few obstacles" and cannot be changed.

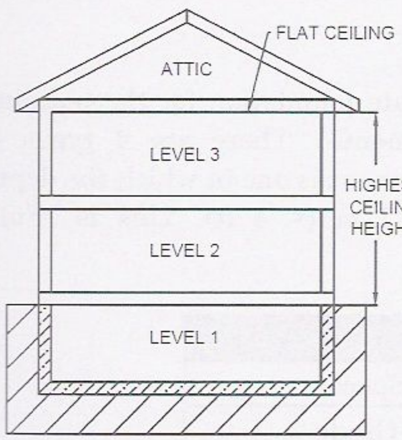
Step iv) Once again, the default height for the anemometer is 10 m above ground level and cannot be changed.

Local Shielding

Shielding is the degree of exposure of the building to wind over a large scale extended over a few kilometers. An example of this may include a building located on a very large property covering many acres of low lying grasslands or the same building located in a densely populated city center.

Step v) Select the appropriate building site. There are 8 classes to choose from ranging from "Open sea" to "City centre" as listed below. For Example-01 use "Open sea".

Building Site
Open sea, fetch > 5km
Mud flats, no vegetation
Open flat terrain, grass
Low crops, x/H > 20
High crops, scattered obstacles
Parkland, bushes, x/H ~ 10
Suburban, forest
City centre



Step vi) Select the appropriate shielding for the walls from the drop down menu. There are five shielding levels to choose from ranging from "No local shielding" to "Complete (by large buildings)" as listed below. This is "No local shielding" in Example-01.

Shielding Levels
No local shielding
Light local shielding
Heavy
Very heavy
Complete (by large buildings)

Step vii) Select the appropriate shielding for the Flue from the drop down menu. Similar to walls, sheltering levels for flues range from "No local shielding" to "Complete (by large buildings)". Typically flue sheltering levels are one level below those of walls, as flues are at higher elevation (typically 1.5 m above highest ceiling in the building) and would be more exposed to wind compared to walls. The Flue sheltering for Example-01 is "No local shielding".

Step viii) The highest ceiling height in feet/meters relative to ground level should be entered. This is defined as the highest point of the ceiling, such as the peak of a cathedral ceiling, to the lowest grade, such as a window well. This is 5.791 m (= 19 ft) Example-01.

Building Configuration

Step ix) Select the building type (detached or semi-detached) from the drop down menu. This is "detached" in Example-01.

Step x) Select the number of storeys above the grade level for the building. There is "one" level above grade in Example-01.

Step xi) Select the appropriate foundation for the building type from the drop down menu. There are 4 types of foundations. A "Shallow" basement is one in which the depth below grade is less than 1.2 m (< 4 ft). This is "Full" basement in Example-01.

Foundation Types
Crawl Space
Slab-on-Grade
Shallow
Full

Step xii) Enter the house volume which includes only conditioned spaces and is based on internal dimensions. The volume shall be entered in m³. For Example-01, the house volume is 445.82 m³ (= 15,744 ft³).

Note A: If the house volume is given in Imperial units (ft³), then the house volume must be converted to m³.

Example-01:

If a house is 15,744 ft³, then convert into m³:

$$15{,}744 \times 0.028317 = 445.82\ m^3$$

Air Leakage/Ventilation

Step xiii) Select the appropriate Air Tightness Type from the drop down menu. There are 5 options for air tightness levels. This is "Energy Tight" in Example-01.

Air Tightness Type
Loose (Pre-1945) (ACH=10.35)
Average (1946-1960) (ACH=4.55)
Present (1961-) (ACH=3.57)
Energy Tight (ACH=1.5)
Custom - BDT values

Note A: If the custom option is selected, the values for the "Custom BDT Data" cells are activated. These cells include input parameters for the BDT (Blower Door Test) data such as the ELA (Equivalent Leakage Area) measured in cm² and ACH (Air Change per Hour) at 50 Pa as shown below. Most testing on Canadian homes would use the ELA @10Pa where as ELA @4Pa is common in the United States. The designer should verify which number is being provided.

Air Leakage/Ventilation			
Air Tightness Type:	Custom - BDT values		
Custom BDT Data:	ELA @ 10 Pa.	56	cm^2
	2	ACH @ 50 Pa	

Step xiv) The total supply and total exhaust flow rates in L/s should be entered for the mechanical ventilation fields. For the total supply and/or exhaust ventilation rates, PVC (Principal Ventilation Capacity) should be entered. PVC requirement which complies with the local building code (NBC, OBC and BCBC), can be looked up from Appendix A, Table 15.

For Example-01:

The house has two bedrooms and has a balanced ventilation system. From Appendix A, Table 15a, the National Building Code requirement for maximum principal ventilation capacity is 28 L/s. Thus, total supply and exhaust ventilation rates are entered at 28 L/s for a balanced ventilation system.

	Total Supply:	Total Exhaust:
Mechanical Ventilation (L/s):	28	28

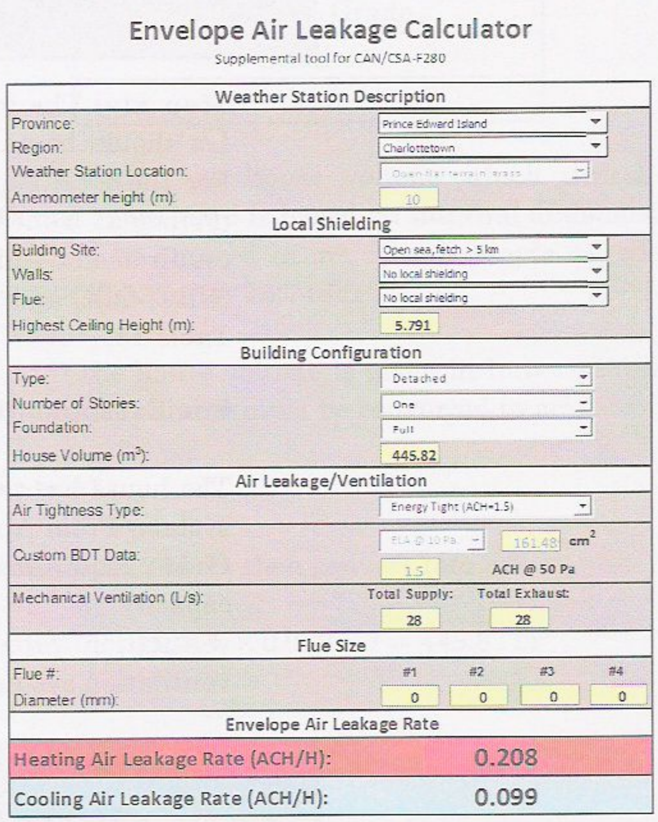
Note A: For balanced ventilation systems with the same total supply/exhaust rates, heating/cooling air leakage rates remain unchanged regardless of which total supply and total exhaust ventilation rates are entered, as long as the same ventilation rate is entered for both total supply and total exhaust. (e.g. having both total supply and exhaust at zero and having both total supply and exhaust at 20 L/s results in the same heating air leakage rate and cooling air leakage rate.)

Flue Size

Step xv) There are four flue diameters available for natural draft flues. Enter the diameter in mm for each flue in the building.

Envelope Air Leakage Rate

The final output at the bottom of the screen shows Heating Air Leakage Rate measured in [ACH/H] as shown below. This value represents the number of times a house volume would be replaced during one hour. For example, an air leakage rate of 2 ACH/H means this house volume is replaced with outdoor air twice during one hour. This is 0.208 ACH/H in Example-01.


Envelope Air Leakage Calculator
Supplemental tool for CAN/CSA-F280

Weather Station Description				
Province:	Prince Edward Island			
Region:	Charlottetown			
Weather Station Location:	Open flat terrain, grass			
Anemometer height (m):	10			
Local Shielding				
Building Site:	Open sea, fetch > 5 km			
Walls:	No local shielding			
Flue:	No local shielding			
Highest Ceiling Height (m):	5.791			
Building Configuration				
Type:	Detached			
Number of Stories:	One			
Foundation:	Full			
House Volume (m³):	445.82			
Air Leakage/Ventilation				
Air Tightness Type:	Energy Tight (ACH=1.5)			
Custom BDT Data:	ELA @ 10 Pa	161.48 cm²		
	1.5	ACH @ 50 Pa		
Mechanical Ventilation (L/s):	Total Supply:	Total Exhaust:		
	28	28		
Flue Size				
Flue #:	#1	#2	#3	#4
Diameter (mm):	0	0	0	0
Envelope Air Leakage Rate				
Heating Air Leakage Rate (ACH/H):	0.208			
Cooling Air Leakage Rate (ACH/H):	0.099			

1.1) Heat Loss Due to Air Leakage

Once the Heating Air Leakage Rate (LR_{airh}) is obtained from the output of the spreadsheet, it is then used in the formula for Building Air Leakage Heat Loss (HL_{leak}) which is given on the Formula Sheet of the HRAI worksheet.

For Example-01, Building Air Leakage Heat Loss is calculated as follows:

BUILDING AIR LEAKAGE HEAT LOSS

$$HL_{leak} = B \times LR_{airh} \times Vb \times HL\Delta T$$

B (M) = 0.33
B (I) = 0.018

$$= \underline{0.018} \times \underline{0.208} \times \underline{15744} \times \underline{76} = \boxed{4480}$$

Where:

HL_{leak} = Air leakage component of heat loss for the building (Btuh or W)

B = 0.018 for Imperial <u>OR</u> 0.33 for Metric units

LR_{airh} = Envelope air leakage rate for heating from CSA AIM2.xls spreadsheet (ACH)

Vb = Building volume (ft^3 or m^3)

$HL\Delta T$ = Heat loss ΔT from top of page 3 of the worksheet (°F or °C)

This value should be recorded as a whole number to the nearest Btu/h or W.

1.2) Air Leakage Heat Loss Multiplier

Level Factor

Level factor is a constant that is used to apportion Air Leakage Heat Loss for each room depending on which level it is located in the house. The level factor is also used in the formula to calculate ventilation heat loss for each room for exhaust only ventilation systems. The level factor table is also provided in Table 7 of Appendix A.

Number of levels / Level	One (e.g. slab on grade bungalow)	Two (e.g. bungalow with basement, two-storey slab on grade)	Three (e.g. two-storey house on basement)	Four (e.g. three-storey house on basement)
Lowest Level	1.0	0.6	0.5	0.4
2nd level up		0.4	0.3	0.3
3rd level up			0.2	0.2
4th level up				0.1

Level factors are used in determining air leakage heat loss multipliers which are used to calculate air leakage heat loss for each room. Once the Air leakage Heat Loss for the building has been calculated, it is used in the table below along with the level factor to calculate the air leakage heat loss multipliers as follows:

Level	Level Factor (LF)	Building Air Leakage Heat Loss (HL_{leak})	Level Conductive Heat Loss: see Section 10 (HL_{clevel})	Air Leakage Heat Loss Multiplier ($LF \times HL_{leak} \div HL_{clevel}$)
1				
2				
3				
4				

$$\textbf{Multiplier} = LF \times HL_{leak} \div HL_{clevel}$$

Where:

Multiplier = Air Leakage Heat Loss Multiplier

LF = Level Factor

$\mathbf{HL_{leak}}$ = Air leakage component of heat loss for the building (calculated previously)

$\mathbf{HL_{clevel}}$ = Total Level Conductive Heat Loss from Section 10, Page 2 of the worksheet.

Note: Air leakage heat loss multipliers should be calculated and recorded in four decimal places in order to ensure accuracy of air leakage heat loss calculations.

After the air leakage heat loss multiplier is calculated, the number must be transferred to the space provided in Section 11 (Air Leakage), page 3 of the worksheet, beside the heading "Heat Loss", under applicable level (LVL 1, LVL 2, LVL 3 or LVL 4) as shown below.

11. AIR LEAKAGE	HEAT LOSS MULTIPLIER				
	HEAT GAIN MULTIPLIER				

1.3) Air Leakage Heat Loss for Each Room

- **Section 11, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

To calculate the Air Leakage Heat Loss for a room, multiply the applicable Air Leakage Heat Loss Multiplier (recorded under (LVL 1, LVL 2, LVL 3 or LVL 4) in Section 11, page 3 of the worksheet) by the Conductive Heat Loss (provided on Section 10, page 3 of the worksheet) for that room.

Room Air Leakage HL

= Room Conductive HL × Air Leakage HL Multiplier

The Air Leakage Heat Loss for a room is then entered in Section 11 in the Heat Loss column for that room. This step must be repeated for each room in the house.

2) Calculation of Heat Loss Due to Continuous Mechanical Ventilation

For purposes of a ventilation heat loss calculation, only heat losses caused by a mechanical ventilation system will be considered.

Regardless of the type of heating system that is being used, the size of the equipment must be able to handle the added ventilation load. It is entirely separate from the air leakage heat loss or gain.

All new construction must have the ventilation load included in the calculation of heat loss for the house as all building codes in Canada require a minimum rate of continuous mechanical ventilation.

If it is to be a heating system replacement, where no mechanical ventilation exists or is to be installed, there is no need for the ventilation calculation.

A credit or allowance is given if a building incorporates some type of heat recovery capacity, such as a Heat Recovery Ventilator (HRV) or Enthalpy Recovery Ventilator (ERV) based on the Apparent Sensible Effectiveness of the unit selected. In essence, the ability of an HRV to warm incoming air to the building is considered in the calculation.

The term "principal ventilation" is the common term used to describe the continuously operating ventilation capacity. It is based on the expected occupancy level of the building, as indicated by the number of bedrooms.

The heat loss due to mechanical ventilation is based on the continuous or principal ventilation capacity rate (PVC) as used in building codes such as the National Building Code of Canada (NBC), the Ontario Building Code (OBC) and the British Columbia Building Code (BCBC).

Alternately, CAN/CSA-F326 may be used to obtain the low continuous ventilation rate (in this case, 40% to 60%) of the Minimum Ventilation Capacity (MVC) as stipulated in the standard. This can be used as the "principal ventilation" rate for calculation purposes.

The methodology used to determine the heat loss due to continuous mechanical ventilation is dependent upon the type of ventilation system. This includes the following:

1) Exhaust only system
2) Direct ducted system
3) Central forced air system

In the first type of mechanical ventilation system, the exhaust only system, the supply air enters the home as infiltration air. It will enter into each room in a distribution pattern similar to that of the Air Leakage calculation procedure shown in the previous section of the manual. Therefore, the Building Ventilation Heat Loss is calculated at the Principal Ventilation Capacity (PVC) rate and then apportioned to each room based on the Level that the room is on and the ratio of room conduction heat losses to the total conduction heat losses for the Level that the room is located on.

For a direct ducted system, PVC (principal ventilation capacity) may be apportioned equally to each applicable room as follows:

$$Qvr = \frac{PVC}{\text{\# of rooms with supply outlets}}$$

Where:
Qvr = Room Ventilation Rate

For the second type of mechanical ventilation system, the direct ducted system, a supply air fan and separate duct system is used to distribute the air to specific rooms in the home. To correctly apportion direct ducted ventilation systems, the Building Ventilation Heat Loss is calculated at the Principal Ventilation Capacity (PVC) rate including any allowance for the effectiveness of any HRV or ERV equipment. This Building Ventilation Heat Loss is then divided equally by the total number of supply outlets, adding these loads to the rooms where the supply outlets are located. In the case of Provincial Codes, ventilation supply air must be distributed as follows:

- NBC: Each bedroom, any storey (including basements and heated crawlspaces) without a bedroom, and if there is no storey without a bedroom, to the principal living area.
- OBC: Each bedroom, to any storey without a bedroom and, if there is no storey without a bedroom, to the principal living area.
- BCBC: Each bedroom and one common area if through-the-wall inlets are used, and into each bedroom, each floor level without a bedroom, and each heated crawlspace if a direct ducted HRV/ERV is used.

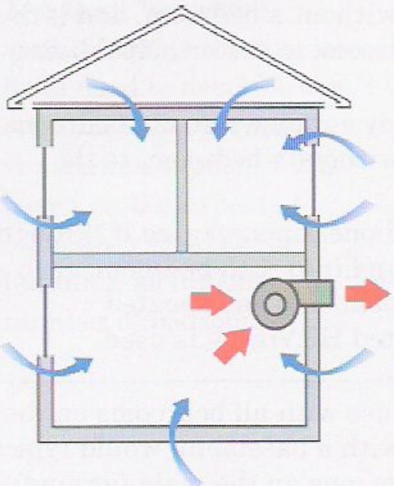
For example, a 3-bedroom house with all bedrooms on the top storey of a two storey house with a basement, would typically have supplies in each bedroom, one on the main (ground) floor level and one in the basement, so a total of 5 supplies and the total calculated ventilation supply air heating and cooling loads would be divided by 5 and added to lines of Section 12b of each appropriate room.

If a CAN/CSA-F326 ventilation system design is used, it must have supply air distributed to all habitable rooms, except those with exhaust from the room, at rates specified in the Standard. The rates are 20 cfm supply to master bedrooms and basement areas greater than 2/3 of the total basement area, and 10 cfm supply to all other habitable rooms. Therefore the ventilation supply air heating/cooling loads should be apportioned based on the proportion of total ventilation air flows delivered to each room.

For the last type of mechanical ventilation system, the Supply to Central Forced Air System, the supply air is supplied to the return air duct of the forced air system and is then distributed to all rooms in proportion to the heating loads. In this case, Building Ventilation Heat Loss is calculated at the Principal Ventilation Capacity (PVC) rate including any allowance for the effectiveness of any HRV or ERV equipment and this load is added directly to the capacity of the heating appliance, without having ventilation heating load distributed to rooms.

The next sections of the manual show the detailed procedures used to apportion the ventilation heat loss.

2.1) Exhaust Only Ventilation System



- **Section 12a, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Heat loss due to an exhaust only ventilation system is calculated in the following steps:

Step i) The heat loss associated with the unbalanced exhaust flow of the principal ventilation must be calculated first as provided in the formula sheet and below:

VENTILATION HEAT LOSS	
HL_{bvent} = C x PVC x HLΔT x (1 - E)	C (M) = 1.2 C (I) = 1.08
= ____ x ____ x ____ x ____ =	

$$HL_{bvent} = C \times PVC \times HL\Delta T \times (1\text{-}E)$$

Where:

HL_{bvent} = Building ventilation heat loss (Btu/h or W)

C = 1.08 for Imperial <u>OR</u> 1.2 for Metric units

PVC = principal or continuous ventilation rate (CFM or L/s)

Note A: Ideally the PVC is provided by the Ventilation system Design. If it is not available, then the PVC may be determined by the designer in accordance with local building code requirements or 40% to 60% of Maximum Ventilation Capacity (MVC) if CAN/CSA-F326 is used (See Appendix A, Table 15a, 15b or 15c).

HLΔT = heat loss ΔT from top of page 3 of the worksheet (°F or °C)

E = Apparent Sensible Effectiveness of the HRV/ERV

Note B: E = 0 for an exhaust only system as no HRV/ERV is being used.

Step ii) Calculate the ventilation heat loss multiplier in the table provided on the formula sheet below.

Case #1: Exhaust Only System (Section 12a)

Multiplier = Level Factor x HL_{bvent} ÷ Level Cond. Heat Loss

Level	LF	HL_{bvent}	LVL Cond. HL	Multiplier
1				
2				
3				
4				

HL_{rvent} = Multiplier x Room Conductive Heat Loss

Multiplier
= Level Factor × HL_{bvent} ÷Level Conductive HL

Where:

Multiplier = Building ventilation heat loss multiplier for exhaust only system

Level Factor = Based on levels, see Appendix A-10, Table 7

HL_{bvent} = Building Ventilation Heat Loss (Btu/h or W)

Level Conductive Heat Loss = The total conductive heat loss of all rooms on a specific level (Btu/h or W)

Once the ventilation heat loss multipliers are calculated for the exhaust only system, transfer the numbers to Section 12a, page 3 of the worksheet, beside the heading "Heat Loss Multiplier" as shown below.

12a. VENTILATION:	HEAT LOSS MULTIPLIER				
EXHAUST ONLY	HEAT GAIN MULTIPLIER				

Step iii) Calculate the ventilation heat loss assigned to each room, using the ventilation heat loss multipliers calculated in Step ii) using the formula below.

HL_{rvent}
= Multiplier × Room Conductive Heat Loss

Where:

HL_{rvent} = Room ventilation heat loss (Btu/h or W)

Multiplier = Ventilation heat loss multipliers recorded in Section 12a, page 3 of the worksheet

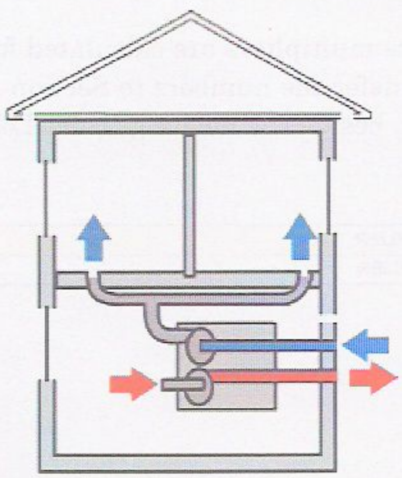
Room Conductive Heat Loss = Total conductive heat loss for the room recorded in Section 10 of the worksheet (Btu/h or W)

This step must be repeated for each room in the house.

2.2) Direct Ducted System

- **Section 12b, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

If a separate duct system is used for the ventilation air, and the flow rate to each room is known, there are two steps in the process of calculating ventilation heat loss.



Direct ducted system

Step i) Calculate the ventilation heat loss multiplier for Direct Ducted System in the space provided on the formula sheet below.

Case #2: Direct Ducted System (Section 12b)	
Multiplier = C x $HL\Delta T$ x (1 - E)	**C (M) = 1.2** **C (I) = 1.08**
Multiplier = ______ x ______ x ______ =	
Q_{vr} = Room Ventilation Rate HL_{rvent}= Multiplier x Q_{vr}	

$$\text{Multiplier} = C \times HL\Delta T \times (1\text{-}E)$$

Where:

Multiplier = Ventilation heat loss multiplier for direct ducted system

C = 1.08 for Imperial OR 1.2 for Metric units

HLΔT = Heat loss ΔT from top of page 3 of the worksheet (°F or °C)

E = Apparent sensible effectiveness of the HRV/ERV

Once the ventilation heat loss multiplier is calculated for the direct ducted system, transfer the multiplier to Section 12b, page 3 of the worksheet, beside the heading "Heat Loss Multiplier" as shown below.

12b. VENTILATION: DIRECT DUCTED SYSTEM	HEAT LOSS MULTIPLIER	
	HEAT GAIN MULTIPLIER	

For a direct ducted system, PVC (principal ventilation capacity) may be apportioned equally to each applicable room as follows:

$$Qvr = \frac{PVC}{\text{\# of rooms with supply outlets}}$$

Where:
Qvr = Room Ventilation Rate

Step ii) Apportion the ventilation flow rate to individual rooms (Q_{vr}) in accordance with the ventilation design (e.g. NBC/OBC/BCBC or CAN/CSA-F326) as explained previously in "Calculation of Heat Loss Due to Continuous Mechanical Ventilation". Enter the number in Section 12b of the worksheet under the heading "Q_{vr}".

Qvr		

Step iii) Calculate the ventilation heat loss assigned to each room, using the ventilation heat loss multipliers calculated in Step i) using the formula below.

$$\mathbf{HL_{rvent} = Multiplier \times Q_{vr}}$$

Where:

HL_{rvent} = Room ventilation heat loss (Btu/h or W)

Multiplier = ventilation heat loss multipliers recorded in Section 12b, page 3 of the work sheet

Qvr = ventilation flow rate for the room calculated in previous Step ii), (CFM or L/s) recorded in Section 12b of the worksheet

Once the ventilation heat loss for each room has been calculated, enter each value in Section 12b of the HRAI Residential Heat Loss and Heat Gain Calculations worksheet.

2.3) Central Forced Air System

- **Section 19, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Heat loss due to supply to a central forced system is calculated using the formula below:

VENTILATION HEAT LOSS	
$HL_{bvent} = C \times PVC \times HL\Delta T \times (1 - E)$	C (M) = 1.2 C (I) = 1.08
= ____ x ____ x ____ x ____ =	

HL_{bvent} **= C x PVC x HL∆T x (1-E)**

Where:

HL_{bvent} = Building ventilation heat loss (Btu/h or W)

C = = 1.08 for Imperial <u>OR</u> 1.2 for Metric units

PVC = Principal or continuous ventilation rate (CFM or L/s)

Note A: Ideally the PVC is provided by the Ventilation system Design. If it is not available then the PVC may be determined by the designer in accordance with local building code requirements or 40% to 60% of Maximum Ventilation Capacity (MVC) if CAN/CSA-F326 is used (see Appendix A, Table 15a, 15b or 15c).

HL∆T = heat loss ∆T from top of page 3 of the worksheet (°F or °C)

E = Apparent sensible effectiveness of the HRV/ERV

Once the ventilation heat loss for the whole building is calculated, it is entered in Section 19, Page 3 of the HRAI Residential Heat Loss and Heat Gain Calculations worksheet.

2.15 Internal Heat Gain (People, Appliances &Lights)

- **Section 13, Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in Heat Loss Calculations.

2.16 Net Load

- **Section 14, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add room Total Conductive Heat Loss (Section 10), room Air Leakage Heat Loss (Section 11), and room Ventilation Heat Loss (Section 12a or 12b, if applicable). Enter amount calculated in Section 14 for each room. This calculation must be made for each room.

2.17 Duct/Pipe through Unconditioned Spaces

- **Section 15, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Where heating ducts or pipes pass through an unheated space on their way to the rooms they serve, they lose some of the heat they are carrying. Therefore, extra heat loss must be added to the capacity of the duct to allow for this loss. In addition, the appliance and distribution system must be sized to account for this heat loss. This extra heat loss is calculated by multiplying the Net Heating Load (Section 14) of a room by a multiplier that takes into account what type of unheated space the ducts or pipes pass through and whether the ducts or pipes are insulated. These duct or pipe loss multipliers are found in Appendix A, Table 8 and Table 9. Duct loss multipliers are used for warm air systems and pipe loss multipliers are used for hot water (hydronic) systems.

Note A: If there is no duct or pipe loss, Section 15 is left blank.

The formulas for calculating duct and pipe losses are as follows:

Duct heat loss
= Room Net Heating Load (Section 14)
× Duct Loss Multiplier

Pipe heat loss
= Room Net Heating Load (Section 14)
× Pipe Loss multiplier

Enter the appropriate amount in Section 15 of the worksheet.

2.18 Total Heat Loss for Each Room

- **Section 16, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add Sections 14 and 15. If there is no duct or pipe loss, the amount from Section 14 is copied to Section 16. This calculation must be made for each room.

2.19 Total Heat Gain for Each Room

- **Section 17, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in heat loss calculations.

2.20 Sub Total Heat Loss (Building)

- **Section 18, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add up Total Heat Loss for Each Room (Section 16). Enter the amount in Section 18.

2.21 Central Forced Air Ventilation Heat Loss

- **Section 19, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

For a central forced air ventilation system, transfer the building ventilation heat loss (HL_{bvent}) calculated in "2.14 Air Change Heat Loss" to Section 19, page 3 of the worksheet.

For all other ventilation systems (Exhaust only system and Direct ducted system), leave Section 19 blank.

2.22 Total Heat Loss (Building)

- **Section 20, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add together the Section 18, Sub Total Heat Loss (Building), and Section 19, Central Forced Air Ventilation Heat Loss (if applicable). This is the total heat loss for the entire building. Enter this amount in Total Heat Loss, Section 20, page 3 of the worksheet.

2.23 Sub Total Heat Gain (Building)

- **Section 21, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in heat loss calculations.

2.24 Central Forced Air Ventilation Heat Gain

- **Section 22, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in heat loss calculations.

2.25 Total Heat Gain (Building)

- **Section 23, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in heat loss calculations.

2.26 Heating System Capacity

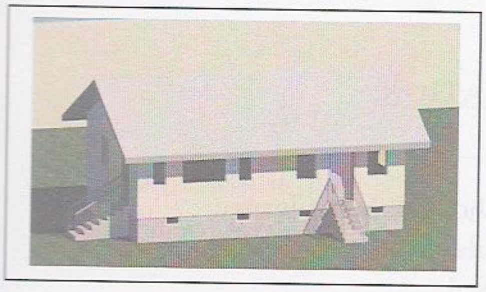
a) The heating system capacity shall not be less than 100% of the building's calculated heat loss.

b) In new CSA F280-12 standard, there is no oversizing limit for heating system capacity.

Note: The CSA committee removed the 40% oversizing limit for heating system capacity to allow greater flexibility in system design, especially with new advancements in heating appliances and strategies. With that in mind, the removal of this oversizing limit should not be used as a valid excuse for negligent oversizing of heating equipments. Designers and contractors are still expected to size the equipments based on their best engineering judgement and discretion.

2.27 Example Heat Loss Calculation

Example-01



SPECIFICATIONS

LOCATION:
This detached house was built in Charlottetown, Prince Edward Island in 2014. The foundation is a basement. There is one storey (Level 2) above grade. Arrange rooms in the following order on the worksheet:

Foundation (Level 1):
OFF (Office), RR (Rec Room), M (Mechanical)

Main Floor (Level 2):
BR2 (Bedroom-2), MB (Master Bedroom), LR (Living Room), K (Kitchen)

DESIGN CONDITIONS:
Winter indoor design temperature 72 °F.
Summer indoor design temperature 75 °F.
Inside conditions apply to all areas of the house

Foundation level (Level 1) ceiling height is 8'.
For the second level (Level 2), the highest ceiling height is 14' and the lowest ceiling height is 9'.
Header height is 12".
Basement wall extends 4' below grade.

SITE CONDITION:
Soil conductivity is high.
Water table is normal.

VENTILATION REQUIREMENTS:
The house will be considered new construction in which a HRV is ducted to return air of central forced air system. Therefore, a ventilation calculation in accordance with CSA F326 or local building code will be required. For this example, use the 2010 NBC.

HRV INFORMATION:

The HRV has an apparent sensible recovery effectiveness of 80% for heating season operation at -13 °F.

Adjusted total recovery efficiency of the HRV for cooling season operation is not reported. Assume zero for the adjusted total recovery efficiency.

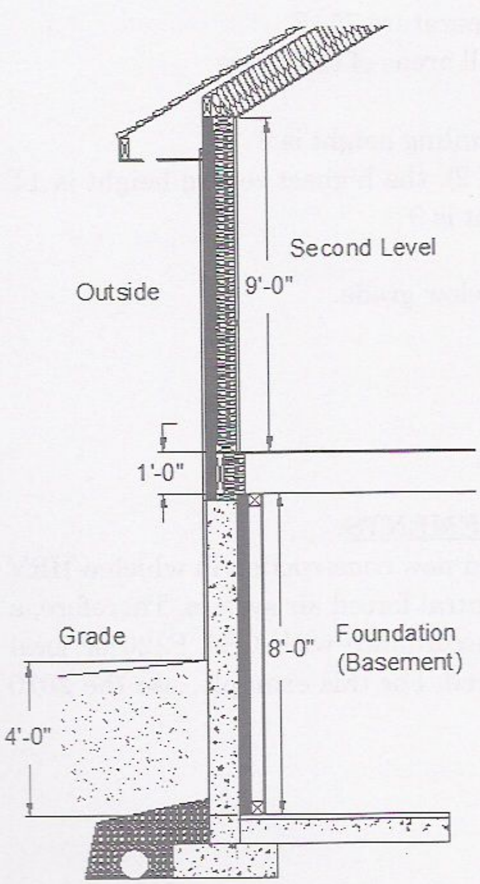
FOUNDATION INFORMATION:

Basement Foundation
Concrete Walls and Floor
Interior wall insulation without slab insulation:
Interior surface of wall insulated over full height
(Use configuration BCIN_1)

ENVELOPE CONSTRUCTION:

Main Floor (Level 2) Ceiling (Cathedral Ceiling)

- Outside air film (vented roof air space)
- 2 x 10" wood ceiling joists @ 16" o.c. filled with R28 glass fibre batt cavity insulation
- 1/2" gypsum board (interior finish)
- Inside air film



Main Floor (Level 2) Wall

- Outside air film
- 3/4" cement stucco cladding
- Plastic housewrap (seal, plastic film)
- 1" extruded polystyrene (Type 4)
- 3/8" plywood sheathing (generic softwood)
- 2" x 4" wood studs @ 16" o.c. filled with R-14 glass fibre batt cavity insulation
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film

Foundation (Level 1) Header

- Outside air film
- 3/4" cement stucco cladding
- Plastic housewrap (seal, plastic film)
- 1" extruded polystyrene (Type 4)
- 3/8" plywood sheathing (generic softwood)
- 1-1/2" lumber (structural framing, spruce-pine-fir)
- Framed with wood floor joists @ 16" o.c. with R-14 glass fibre batt cavity insulation along joist parallel to exterior wall
- Inside air film

Foundation (Level 1) Wall

- Outside air film
- 3/4" cement stucco cladding
- 8" concrete (150 lb/ft³)
- 3" extruded polystyrene (XPS) (Type 4)
- 1" x 4" strapping applied flat to the wall
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film

Foundation (Level 1) Floor

- 4" concrete slab (150 lb/ft³)
- Linoleum tile
- Inside air film, floor (heat flow down)

WINDOWS:

Double glazed, operable aluminium, metal spacers, clear coatings, ½" glazing spacing, argon filled.
No interior shading.

Foundation level windows have height of 2'.
Second level windows have height of 4'.

DOORS:

Insulated fibreglass polyurethane core with storm.

Unless otherwise stated, door heights are 7'.

AIR LEAKAGE:

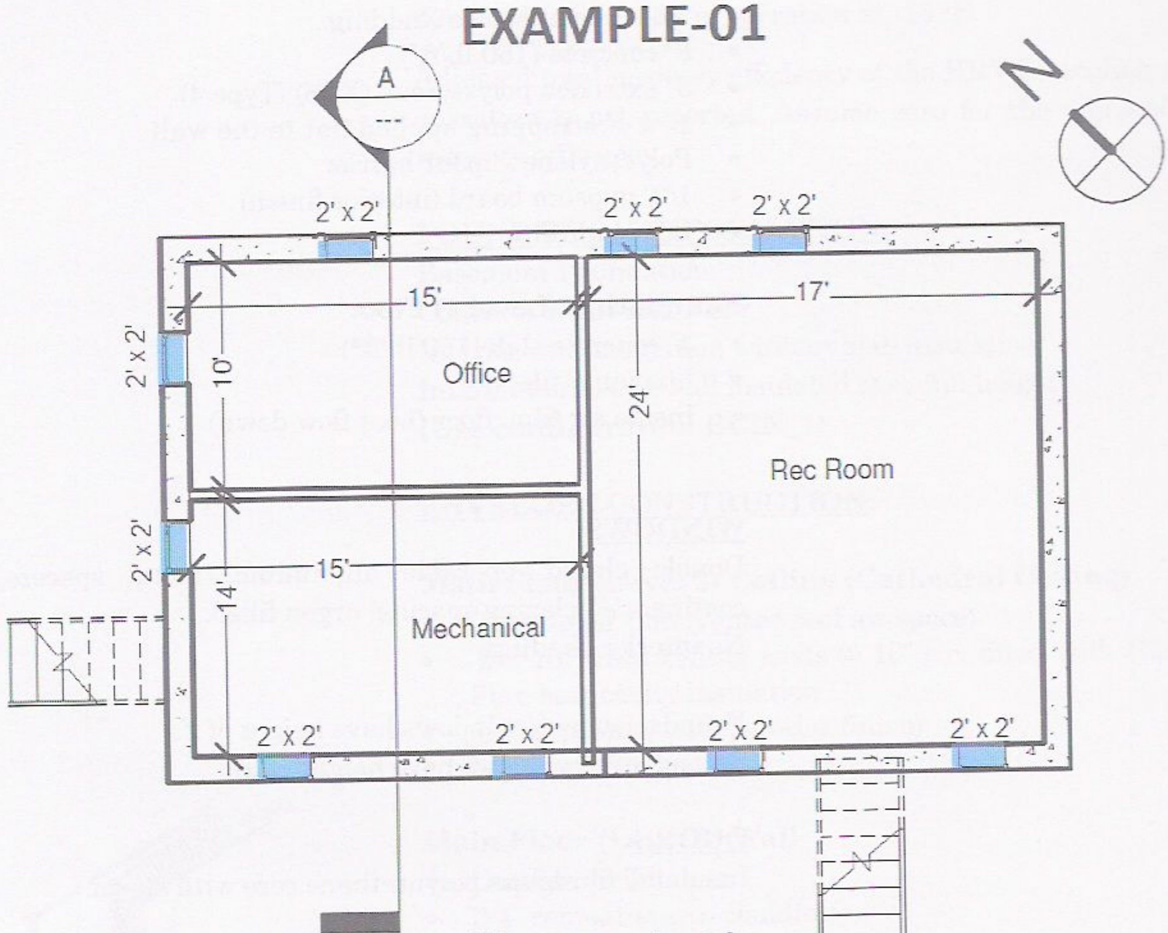
Air tightness level: Energy Tight
Building Site (Shielding class): Open sea
Sheltering level – Walls: No local shielding.
Sheltering level – Flues: No local shielding.
Heating air leakage rate (LR_{airh}) = 0.208/h
Cooling air leakage rate (LR_{airc})= 0.099/h

PEOPLE AND APPLIANCES:

Allow for all people in the Living Room
Appliance and plug loads are distributed to the Living Room and Kitchen

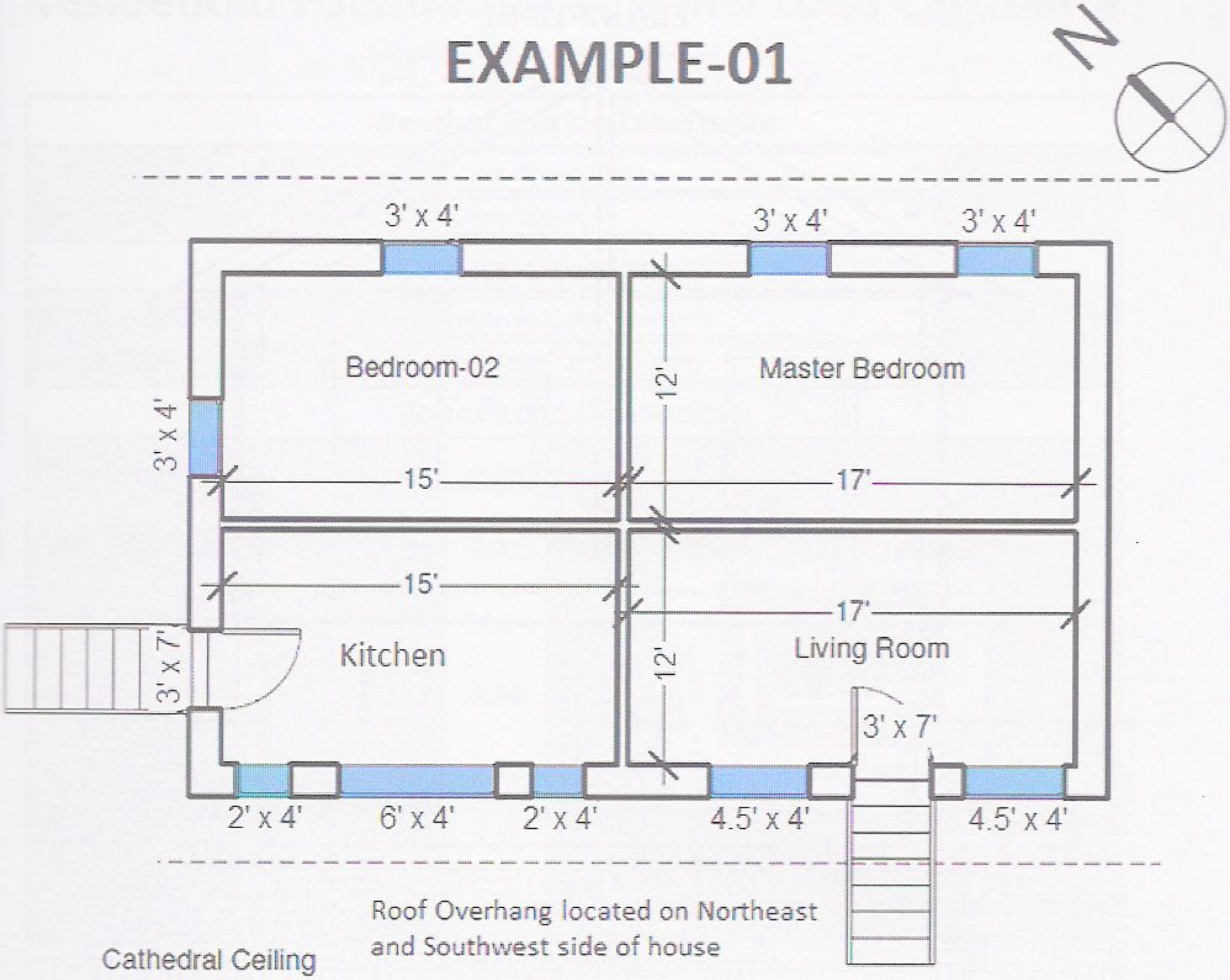
***Note A: ignore duct/pipe heat loss & gain in this calculation**

EXAMPLE-01



Foundation

EXAMPLE-01



Cathedral Ceiling

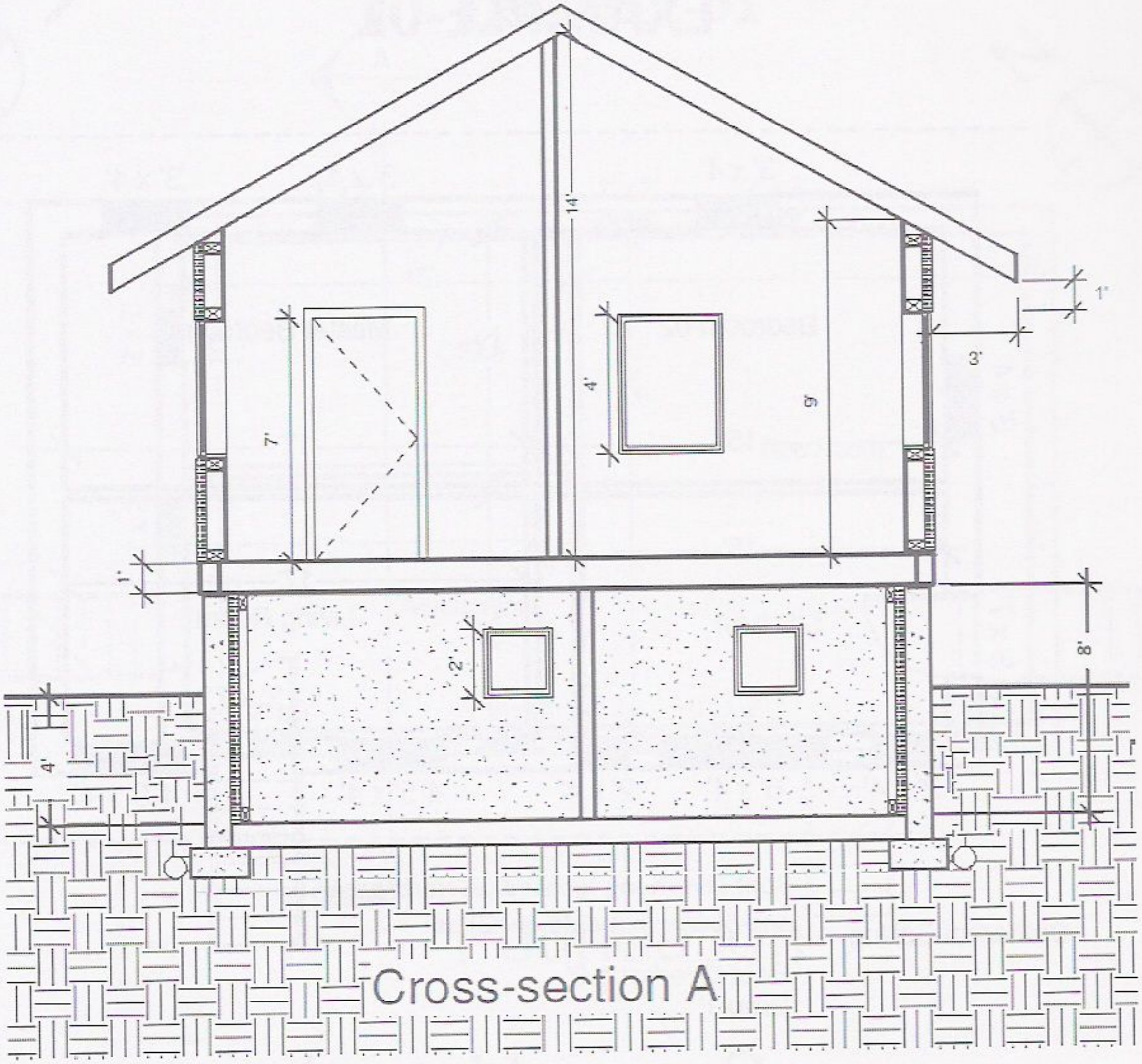
Roof Overhang located on Northeast and Southwest side of house

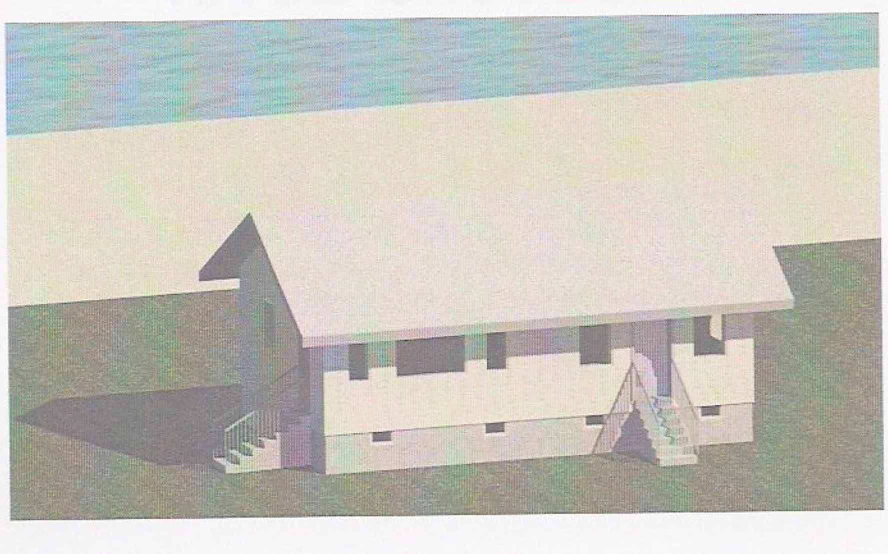
Roof Overhang 3'
Drop 1'

Second Level

BLUE = WINDOW

EXAMPLE-01

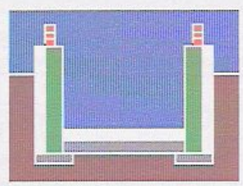




Residential Foundation Thermal Load Calculator

Supplemental tool for CAN/CSA-F280

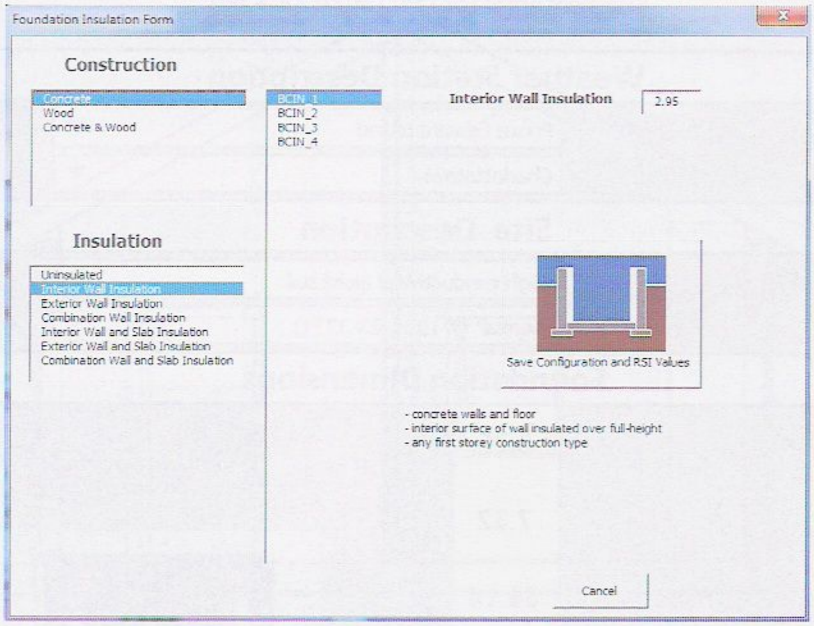
Weather Station Description		
Province:	Prince Edward Island	
Region:	Charlottetown	
Site Description		
Soil Conductivity:	High conductivity: moist soil	
Water Table:	Normal (7-10 m, 23-33 Ft)	
Foundation Dimensions		
Floor Length (m):	9.75	
Floor Width (m):	7.32	
Exposed Perimeter (m):	34.14	
Wall Height (m):	2.44	
Depth Below Grade (m):	1.22	
Window Area (m^2):	3.34	
Door Area (m^2):	0	
Radiant Slab		
Heated Fraction of the Slab:	0	
Fluid Temperature (°C):	33	
Design Months		
Heating Month	1	
Foundation Loads		
Heating Load (Watts):	**1484**	



Conductive Heat Loss for Basement Foundation (includes Heat Loss from above grade basement walls)
= 1484 W
= 1484 × 3.412 = 5063 Btu/h

Basement conductive heat loss is to be apportioned to each room at basement level based on exposed perimeter ratio.

Insulation Configuration for Foundation Thermal Load Calculator



Structure		Foundation (Level 1) Wall – Below Grade - Excluding Concrete Wall & Air Film	
Layer		R-Value	Reference
8" concrete (150 lb/ft³) (= 8 × 0.058)		Excl.	Excl.
Interior Side of Concrete Wall	3" extruded polystyrene (XPS) (Type 4)	15.15	App. B, B-3
	1" × 4" strapping applied without cavity insulation	1.14	App. A, Table 1
	Polyethylene vapour barrier	-	-
	1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)		Excl.	Excl.
R-VALUE ON INTERIOR SIDE OF CONCRETE WALL		**16.73**	
RSI-VALUE = R-Value × 0.1761		**2.95**	

Structure	Foundation (Level 1) Slab on Grade Floor – Excluding Concrete Slab & Air Film	
Layer	R-Value	Reference
4" concrete slab (150 lb/ft³)	Excl.	Excl.
Linoleum tile	0.05	App. B, B-5
Inside air film - floors	Excl.	Excl.
R-VALUE ABOVE CONCRETE SLAB	**0.05**	**Uninsulated**
RSI-VALUE = R-Value × 0.1761	**0.01**	

Envelope Air Leakage Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description	
Province:	Prince Edward Island
Region:	Charlottetown
Weather Station Location:	Open flat terrain, grass
Anemometer height (m):	10
Local Shielding	
Building Site:	Open sea, fetch > 5 km
Walls:	No local shielding
Flue:	No local shielding
Highest Ceiling Height (m):	5.791
Building Configuration	
Type:	Detached
Number of Stories:	One
Foundation:	Full
House Volume (m^3):	445.82
Air Leakage/Ventilation	
Air Tightness Type:	Energy Tight (ACH=1.5)
Custom BDT Data:	ELA @ 10 Pa. 161.48 cm^2; 1.5 ACH @ 50 Pa
Mechanical Ventilation (L/s):	Total Supply: 28; Total Exhaust: 28
Flue Size	
Flue #:	#1, #2, #3, #4
Diameter (mm):	0, 0, 0, 0
Envelope Air Leakage Rate	
Heating Air Leakage Rate (ACH/H):	**0.208**
Cooling Air Leakage Rate (ACH/H):	**0.099**

CALCULATIONS:

Heat Loss ΔT = IDT – ODT = 72 – (-4) = 76 °F

(Appendix D, page D-18)

R-value Calculation:

Structure	Main Floor (Level 2) Ceiling (Cathedral Ceiling)	
Layer	R-Value	Reference
Outside air film (vented roof air space)	0.17	App. B, B-2
2" × 10" wood ceiling joists @ 16" o.c. filled with R28 glass fibre batt cavity insulation	21.19	App. A, Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (ceiling)	0.62	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**22.42**	

Structure	Main Floor (Level 2) Wall	
Layer	R-Value	Reference
Outside air film	0.17	App. B, B-2
3/4" cement stucco cladding (= 0.75 × 0.13)	0.10	App. B, B-2
Plastic housewrap (seal plastic film)	-	-
1" extruded polystyrene (XPS) (Type 4)	5.05	App. B, B-3
3/8" plywood sheathing (generic softwood) (= 0.375 × 1.26)	0.47	App. B, B-4
2" × 4" wood studs @ 16" o.c. filled with R14 batt insulation	9.22	App. A, Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**16.13**	

Structure	Foundation (Level 1) Header	
Layer	R-Value	Reference
Outside air film	0.17	App. B, B-2
3/4" cement stucco cladding (= 0.75 × 0.13)	0.10	App. B, B-2
Plastic housewrap (seal plastic film)	-	-
1" extruded polystyrene (XPS) (Type 4)	5.05	App. B, B-3
3/8" plywood sheathing (generic softwood) (= 0.375 × 1.26)	0.47	App. B, B-4
1-1/2" lumber (structural framing, spruce-pine-fir) (= 1.5 × 1.23)	1.85	App. B, B-4
Framed with wood floor joists @ 16" o.c. with R14 batt insulation	14.03	App. A, Table 1
Inside air film (walls)	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**22.35**	

Structure	Foundation (Level 1) Wall – Above Grade	
Layer	R-Value	Reference
Outside air film	0.17	App. B, B-2
3/4" cement stucco cladding (= 0.75 × 0.13)	0.10	App. B, B-2
8" concrete (150 lb/ft³) (= 8 × 0.058)	0.46	App. B, B-4
3" extruded polystyrene (XPS) (Type 4)	15.15	App. B, B-3
1" × 4" strapping applied without cavity insulation	1.14	App. A, Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**18.14**	

Windows R-Value = 1.14 (Appendix A, Table 3)

Doors R-Value = 6.81 (Appendix A, Table 6)

Windows SHGC = 0.63 (Appendix A, Table 3)

Heating Air Leakage Rate (LR_{airh}) = 0.208
(from Envelope Leakage Calculator)

HL_{leak}
$= B \times LR_{airh} \times Vb \times HL\Delta T$
$= 0.018 \times 0.208 \times 15744 \times 76 = 4480$ Btu/h

Air Leakage Heat Loss Multiplier

= Level Factor × HL_{leak} ÷ Level Conductive Heat Loss

Level 1 Air Leakage Heat Loss Multiplier

$= 0.6 \times 4480 \div 7843 = 0.3427$

Level 2 Air Leakage Heat Loss Multiplier

$= 0.4 \times 4480 \div 16086 = 0.1114$

HL_{bvent} $= C \times PVC \times HL\Delta T \times (1\text{-}E)$

$= 1.08 \times 59 \times 76 \times (1 - 0.80) = 969$ Btu/h

These are the basic calculations to be transferred to the worksheet. From the R-values and various factors, the required multipliers can be calculated, and from the dimensions on the house plans, all required areas can be calculated. After entering the multipliers and area on the worksheet, the heat loss and heat gain can be calculated.

HRAI Residential Heat Loss and Heat Gain Calculations			Page 1 of 8
	BUILDING LOCATION		
HRAI	Model: Example-01	Site: Millwood Heights	
	Address: 456 Mills Road	Lot: Lot 5	
	City and Province: Charlottetown, PEI	Postal Code: C2E 5F4	

SUBMITTED FOR		**DESIGNED/SUBMITTED BY:**	
Name	Carol Collins	Name	Mark Jacob
	CC Builders	Company	MJ Consulting Inc.
Address	123 Ilusion Road	Address	654 Chestnut Drive
City and Province	Charlottetown, PEI Postal Code A1A 1A1	City and Province	Charlottetown, PEI Postal Code A1B 1C1
Telephone	123-452-2143	Telephone	123-562-5633
E-mail	Carol@CCBuilders.ca	E-mail	Mark@MJConsulting.ca

FOR DESIGNER'S USE:			
Signature:	Date Prepared (MM/DD/YY)	HRAI #	Other Certification # (e.g. BCIN)
	01/01/2015	xxxxx	BCIN: xxxxx

SECTION A	**BUILDING CONSTRUCTION DETAILS**		
Plan & Drawing No:	Any-Design Drawings Dated 08/09/2014		
Attachment:	Detached	Front facing:	Southwest Assumed ☐ Yes ☑ No
No. of Stories	1 + Basement	Air tightness:	Energy Tight Assumed ☑ Yes ☐ No
Weather location	Charlottetown, PEI Ventilated ☑ Yes ☐ No	Local Shielding:	No local shielding
HRV Model	Model-XXXXX6 ☐ N/A	Internal Shading:	No interior shading Occupants: 3
		Units:	☑ Imperial ☐ Metric

Building Envelope Assemblies

Above Grade Walls		**Windows & Skylights**	
Structure: MFW	3/4" cement stucco cladding, 1" Type 4 XPS, 2 x 4 wood studs @ 16" filled with R14 glass fibre	Structure: WN	Double glazed, operable aluminum, metal spacers, clear coatings, 1/2" glazing spacing,
Structure: FW	3/4" cement stucco cladding, 8" concrete, 3" Type 4 XPS, 1 x 4 strapping	Structure:	
Structure:		Structure:	
Structure:		Structure:	

Below Grade Walls		**Headers**	
Structure: BGW	8" concrete, 3" Type 4 XPS,1 x 4 strapping	Structure: H	3/4" cement stucco cladding, 1" Type XPS, 1-1/2" lumber, framed @ 16" filled with R14 batt
Structure:		Structure:	

Ceilings		**Floors on Soil**	
Structure: EXC	2 x 10 wood ceiling joists @ 16" o.c. filled with R28 glass fibre batt insulation	Structure: FF	Linoleum tile, 4" concrete slab
Structure:		Structure:	

Doors		**Exposed Floors**	
Structure: D	Insulated fibreglass polyurethane core with storm	Structure:	
Structure:		Structure:	

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HRAI Residential Heat Loss and Heat Gain Calculations

SECTION B — DESIGN CONDITIONS

HEAT LOSS			HEAT GAIN		
Outdoor Design Temperature Heating (ODT)	-4	°F / ~~°C~~	Outdoor Design Temperature Cooling (ODT)	79	°F / ~~°C~~
Indoor Design Temperature (IDT)	72	°F / ~~°C~~	Indoor Design Temperature (IDT)	75	°F / ~~°C~~
Mean Soil Temperature	46	°F / ~~°C~~	North Latitude	46	°
			Summer Mean Daily Temperature Range	16	°F / ~~°C~~
Building Volume (Vb)	15744	ft^3 / ~~m^3~~	Building Conditioned Area	1536	ft^2 / ~~m^2~~

HRV Apparent Sensible Effectiveness = 0.80 (insert N/A if no HRV/ERV installed)

Ventilation System:

☐ Case #1: Exhaust Only System ☐ Case #2: Direct Ducted System ☑ Case #3: Central Forced Air System

SECTION C — ROOM HEAT LOSS / HEAT GAIN SUMMARY

Level	Room Name	Total Heat Loss Calculated Section 16 Btuh/~~W~~	Total Heat Gain Calculated Section 17 Btuh/~~W~~	Level	Room Name	Total Heat Loss Calculated Section 16 Btuh/~~W~~	Total Heat Gain Calculated Section 17 Btuh/~~W~~
1	OFF	2347					
1	RR	5216					
1	M	2967					
2	BR2	3817					
2	MB	4009					
2	LR	4985					
2	K	5068					
				SUB TOTAL		28409 Section 18	Section 21

SECTION D — BUILDING HEAT LOSS SUMMARY

Building Sub Total Heat Loss	(Section 18)	28409	Btuh/~~W~~
Central Forced Air Ventilation Heat Loss	(Section 19)	969	Btuh/~~W~~ *Only applicable for ventilation case #3
Total Building Heat Loss	(Section 20)	**29378**	Btuh/~~W~~

SECTION E — BUILDING HEAT GAIN SUMMARY

Building Sub Total Heat Gain	(Section 21)		Btuh/~~W~~
Central Forced Air Ventilation Heat Gain	(Section 22)		Btuh/~~W~~ *Only applicable for ventilation case #3
Total Building Heat Gain	(Section 23)		Btuh/~~W~~

Notes:

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HRAI Residential Heat Loss and Heat Gain Calculations						Page 3 of 8		
		HL ΔT =	76	HG ΔT =				
COMPONENTS	STRUCTURE	EFFECTIVE R-VALUE Col 1	$\frac{HL\Delta T}{R}$ Col 2	SC Col 3	$\frac{(HG\Delta T + SC)}{R}$ Col 4	P_E 25 / H 8 / A_F 150 / Area	LVL 1 / RM OFF / HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS	MFW							
	FW					100.00		
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH	1.14	66.67		THGM 21.77			
	S				THGM			
	E/W				THGM			
	NE/NW	1.14	66.67		THGM 42.57	8.00	533	
	SE/SW	1.14	66.67		THGM 65.24			
	HOR				THGM			
3.EXPOSED DOORS	D	6.81	11.16					
4.NET EXPOSED WALLS	MFW	16.13	4.71				Do not Calculate for Basement	
	FW	18.14	4.19			92.00		
5.HEADER AREAS	H	22.35	3.40			25.00	85	
6.EXPOSED CEILINGS	EXC	22.42	3.39	27				
7.EXPOSED FLOORS								
8.OTHER								
9.FOUNDATION CONDUCTIVE HEAT LOSS	☑ BASEMENT ☐ SLAB ON GRADE						1130	

		LVL 1	LVL 2	LVL 3	LVL 4			
10. TOTAL CONDUCTIVE	TOTAL HEAT LOSS	7843	16086				1748	
	TOTAL HEAT GAIN							
11. AIR LEAKAGE	HEAT LOSS MULTIPLIER	0.3427	0.1114				599	
	HEAT GAIN MULTIPLIER							
12a. VENTILATION: EXHAUST ONLY	HEAT LOSS MULTIPLIER							
	HEAT GAIN MULTIPLIER							
12b. VENTILATION: DIRECT DUCTED SYSTEM	HEAT LOSS MULTIPLIER					Qvr		
	HEAT GAIN MULTIPLIER							
13. INTERNAL HEAT GAIN (PEOPLE, LIGHTS, APPLIANCES, PLUG LOADS)								
14. NET LOADS	ADD SECTIONS (10 + 11 + 12 + 13)						2347	
15. DUCT / PIPE HEAT LOSS/GAIN THROUGH UNCONDITIONED SPACES						LOSS		
						GAIN		
16. TOTAL HEAT LOSS FOR EACH ROOM	ADD SECTIONS (14 + 15)					LOSS	2347	
17. TOTAL HEAT GAIN FOR EACH ROOM	ADD SECTIONS (14 + 15) × 1.3					GAIN		

18. SUB TOTAL HEAT LOSS (SUM OF SECTION 16)	28409	20. TOTAL HEAT LOSS ADD SECTIONS (18 + 19)	29378
19. CENTRAL FORCED AIR VENTILATION HEAT LOSS	969		
21. SUB TOTAL HEAT GAIN (SUM OF SECTION 17)		23. TOTAL HEAT GAIN ADD SECTIONS (21 + 22)	
22. CENTRAL FORCED AIR VENTILATION HEAT GAIN			

HRAI Residential Heat Loss and Heat Gain Calculations								Page 4 of 8		
COMPONENTS	STRUCTURE	P_E 58	LVL	1	P_E 29	LVL	1	P_E 27	LVL	2
		H 8	RM	RR	H 8	RM	M	H 9	RM	BR2
		A_F 408	HEAT	HEAT	A_F 210	HEAT	HEAT	A_F 180	HEAT	HEAT
		Area	LOSS	GAIN	Area	LOSS	GAIN	Area	LOSS	GAIN
1.GROSS EXPOSED WALLS	MFW							273.00		
	FW	232.00			116.00					
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH									
	S									
	E/W									
	NE/NW	8.00	533		4.00	267		24.00	1600	
	SE/SW	8.00	533		8.00	533				
	HOR									
3.EXPOSED DOORS	D									
4.NET EXPOSED WALLS	MFW		Do not Calculate for Basement			Do not Calculate for Basement		249.00	1173	
	FW	216.00			104.00					
5.HEADER AREAS	H	58.00	197		29.00	99				
6.EXPOSED CEILINGS	EXC							195.00	661	
7.EXPOSED FLOORS										
8.OTHER										
9.FOUNDATION HL			2622			1311				
10. TOTAL CONDUCTIVE			3885			2210			3434	
11. AIR LEAKAGE			1331			757			383	
12a. VENTILATION: EXHAUST ONLY										
12b. VENTILATION: DIRECT DUCTED SYSTEM		Qvr			Qvr			Qvr		
13. INTERNAL HEAT GAIN										
14. NET LOADS			5216			2967			3817	
15. DUCT / PIPE HEAT LOSS / GAIN		LOSS			LOSS			LOSS		
		GAIN			GAIN			GAIN		
16. TOTAL HL (ROOM)		LOSS	5216		LOSS	2967		LOSS	3817	
17. TOTAL HG (ROOM)		GAIN			GAIN			GAIN		

HRAI Residential Heat Loss and Heat Gain Calculations									Page 5 of 8	
COMPONENTS	STRUCTURE	P_E 29	LVL 2		P_E 29	LVL 2		P_E 27	LVL 2	
		H 9	RM MB		H 9	RM LR		H 9	RM K	
		A_F 204			A_F 204			A_F 180		
		Area	HEAT LOSS	HEAT GAIN	Area	HEAT LOSS	HEAT GAIN	Area	HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS	MFW	291.00			291.00			273.00		
	FW									
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH				20.70	1380		23.00	1533	
	S									
	E/W									
	NE/NW	24.00	1600							
	SE/SW				15.30	1020		17.00	1133	
	HOR									
3.EXPOSED DOORS	D				21.00	234		21.00	234	
4.NET EXPOSED WALLS	MFW	267.00	1258		234.00	1102		212.00	999	
	FW									
5.HEADER AREAS	H									
6.EXPOSED CEILINGS	EXC	221.00	749		221.00	749		195.00	661	
7.EXPOSED FLOORS										
8.OTHER										
9.FOUNDATION HL										
10. TOTAL CONDUCTIVE			3607			4485			4560	
11. AIR LEAKAGE			402			500			508	
12a. VENTILATION: EXHAUST ONLY										
12b. VENTILATION: DIRECT DUCTED SYSTEM		Qvr			Qvr			Qvr		
13. INTERNAL HEAT GAIN										
14. NET LOADS			4009			4985			5068	
15. DUCT / PIPE HEAT LOSS / GAIN		LOSS			LOSS			LOSS		
		GAIN			GAIN			GAIN		
16. TOTAL HL (ROOM)		LOSS	4009		LOSS	4985		LOSS	5068	
17. TOTAL HG (ROOM)		GAIN			GAIN			GAIN		

HRAI Residential Heat Loss and Heat Gain Calculations
Formula Sheet (For Air Leakage / Ventilation Calculation)

BUILDING AIR LEAKAGE HEAT LOSS

B (M) = 0.33
B (I) = 0.018

$HL_{leak} = B \times LR_{airh} \times Vb \times HL\Delta T$

$= 0.018 \times 0.208 \times 15744 \times 76 = \boxed{4480}$

BUILDING AIR LEAKAGE HEAT GAIN

B (M) = 0.33
B (I) = 0.018

$HG_{leak} = B \times LR_{airc} \times Vb \times HG\Delta T$

= ____ x ____ x ____ x ____ = ☐

AIR LEAKAGE HEAT LOSS/GAIN MULTIPLIER TABLE (SECTION 11)

Level	Level Factor (LF)	Building Air Leakage Heat Loss (HL_{leak})	Level Conductive Heat Loss: see Section 10 (HL_{clevel})	Air Leakage Heat Loss Multiplier ($LF \times HL_{leak} \div HL_{clevel}$)
1	0.6	4480	7843	0.3427
2	0.4		16086	0.1114
3				
4				

Air Leakage Heat Gain Multiplier = $\frac{HG_{leak}}{\text{Building Conductive Heat Gain}}$ = ______ = ☐

VENTILATION HEAT LOSS

C (M) = 1.2
C (I) = 1.08

$HL_{bvent} = C \times PVC \times HL\Delta T \times (1 - E)$

$= 1.08 \times 59 \times 76 \times 0.20 = \boxed{969}$

VENTILATION HEAT GAIN

C (M) = 1.2
C (I) = 1.08

$HG_{bvent} = C \times PVC \times HG\Delta T \times (1 - ATRE)$

= ____ x ____ x ____ x ____ = ☐

Case #1: Exhaust Only System (Section 12a) — Heat Loss

Multiplier = Level Factor x HL_{bvent} ÷ Level Cond. Heat Loss

Level	LF	HL_{bvent}	LVL Cond. HL	Multiplier
1				
2				
3				
4				

HL_{rvent} = Multiplier x Room Conductive Heat Loss

Case #1: Exhaust Only System (Section 12a) — Heat Gain

Multiplier = $\frac{HG_{bvent}}{\text{Building Conductive Heat Gain}}$

Multiplier = ______ = ☐

HG_{rvent} = Multiplier x Room Conductive Heat Gain

Case #2: Direct Ducted System (Section 12b) — Heat Loss

C (M) = 1.2
C (I) = 1.08

Multiplier = $C \times HL\Delta T \times (1 - E)$

Multiplier = ____ x ____ x ____ = ☐

Q_{vr} = Room Ventilation Rate
HL_{rvent} = Multiplier x Q_{vr}

Case #2: Direct Ducted System (Section 12b) — Heat Gain

C (M) = 1.2
C (I) = 1.08

Multiplier = $C \times HG\Delta T \times (1 - ATRE)$

Multiplier = ____ x ____ x ____ = ☐

Q_{vr} = Room Ventilation Rate
HG_{rvent} = Multiplier x Q_{vr}

Case #3: Central Forced Air System (Section 19)

Enter HL_{bvent} in Section 19

Case #3: Central Forced Air System (Section 22)

HG_{bvent} x 1.3 = ☐ x 1.3 = ☐
(enter in Section 22)

HRAI WINDOW SHADING WORKSHEET

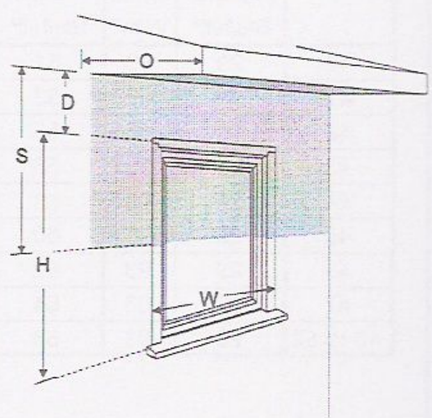
Page 7 of 8

Latitude = 46 °

Level	2	2	2	2			
Room Name	LR	K	BR2	MB			
Direction Window Faces	SW	SW					S
W (ft / m) Width of Window	9'	10'					3
H (ft / m) Height of Window	4'	4'					4
A (ft² / m²) Total Window Area	36'	40'					
O (ft / m) Width of Overhang	3'	3'					2
F (see Table below) F-Shade Factor	1.1	1.1					2.0
S (ft / m) S = F x O Shade Line	3.3	3.3					4
D (ft / m) Drop	1'	1'					1
SA (ft² / m²) SA = (S-D) x W Shaded Area	20.7	23					
UA (ft² / m²) UA = A - SA Unshaded Area	15.3	17					

NOTES:

1. Shaded area SA will be marked on the HRAI Worksheets as "north"
2. Unshaded area (UA) will be marked on the HRAI Worksheets as the direction the window actually faces
3. Shading calculations are not required for north, northeast and northwest facing windows.
4. If the shaded area (SA) is greater than the window area (A), then: SA = A Shaded area (SA) is never more than window area (A)
5. If shaded area (SA) is negative use a value of zero.



F Shade Factor							
Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

TRANSPARENT ASSEMBLY HEAT GAIN MULTIPLIER (THGM) WORKSHEET

Transparent Assembly Heat Gain Multiplier (THGM)

$$\text{THGM} = \frac{\text{HG}\Delta\text{T}}{\text{R}} + (\text{SHGC} \times \text{SOLAR} \times \text{ISF})$$

THGM Calculation Table

		Facing Direction						
		North & Shaded	South	East / West	Northeast / Northwest	Southeast / Southwest	Horizontal	
North Latitude				46	°		44	
HGΔT				4	°F		6	4
Effective R-value		1.14				1.14	1.48	2.84
#1	$\frac{\text{HG}\Delta\text{T}}{\text{R}}$	3.5			3.51	3.5	4.05	1.4
#2	SHGC	0.63			0.63	0.63	0.40	0.43
#3	SOLAR	29			62	98	92	60
#4	ISF	1			1	1	1	1
#5	(#2) × (#3) × (#4)	18.27			39.06	61.74	36.8	25.8
#6	THGM=(#1) + (#5)	21.77			42.57	65.24		27.2

SOLAR = Estimated Solar Radiation

Latitude	North & Shaded		South		East / West		Northeast / Northwest		Southeast / Southwest		Horizontal	
	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²
40	29	93	51	160	90	285	62	194	80	252	169	534
41	29	93	53	166	90	285	62	194	83	261	169	534
42	29	93	55	172	90	285	62	194	86	271	169	534
43	29	93	56	178	90	285	62	194	89	280	169	534
44	29	93	58	184	90	285	62	194	92	290	169	534
45	29	93	60	190	90	285	62	194	95	299	169	534
46	29	93	62	196	90	285	62	194	98	309	169	534
47	29	93	64	202	90	285	62	194	101	318	169	534
48 to 82	29	93	66	208	90	285	62	194	104	328	169	534

ISF = Internal Shading Factors

Type of interior shading	Type of glazing systems			
	Single	Double	Triple	Heat Mirror
No interior shades	1	1	1	1
Interior blinds, curtains, and etc.	0.50	0.55	0.57	0.60
Interior reflective metallic blinds or screens	0.35	0.37	0.40	0.44

3 Heat Gain Calculations

Purpose of Chapter

This section examines the steps involved in determining the heat gain in residential buildings using the HRAI Residential Heat Loss and Heat Gain Calculations worksheet. Where possible, Example-01 will be used to relate between the procedures presented in this section and how these are applied using the worksheet.

Table of Contents

3.1 Introduction

This chapter will proceed through the basics of determining heat gain by using the HRAI worksheet.

As previously noted under Heat Loss Calculations, there are two situations which may be encountered:

i) A new building is being proposed, and the heat gain calculations will be based on a set of plans and specifications; and

ii) An existing building is being analyzed, and field measurements and notes will be required.

After obtaining all of the required building information, the designer is ready to proceed with the processing of the Residential Heat Loss and Heat Gain Calculations worksheet. As with Heat Gain Calculations, information from the appendices of this manual will also be required.

Note: There are three sets of appendices.

1. A-B-C Imperial Units (green)
2. A-B-C SI (Metric) Units (blue)
3. D Temperature Data for Locations Across Canada in both Imperial and SI Units (yellow)

Begin by taking an HRAI Residential Heat Loss and Heat Gain Calculations worksheet, page 1.

First, fill in the project building location information which includes:

i) Model

ii) Address

iii) City and Province

iv) Postal Code

v) Project Building Site & Lot

Then, complete customer and designer information as it applies.

Next, fill in data and assumptions for heat loss and heat gain calculations that are listed in Section A, Building Construction Details. In this section, a designer is asked to fill out information such as building plan & drawing number and building characteristics which includes front facing direction, air tightness, wind exposure and etc.

A designer also needs to enter simple structure label and corresponding descriptions for building envelope assemblies (e.g. walls, floors, ceilings, doors, windows and skylights) under "Building Envelope Assemblies".

NOTE: The information listed above would have been completed if the Heat Loss calculation was calculated prior to Heat Gain calculation.

3.2 Design Conditions

- **Section B, HRAI Residential Heat Loss and Gain Calculations, page 2**

Step i) Decide which units will be used throughout the entire calculation procedure.

Step ii) From Appendix D, for the location where the building is situated, transfer the following information into Section B, Design Conditions, Heat Gain Column, page 2:

a) Outdoor Design Temperature Cooling

b) North Latitude

c) Summer Mean Daily Temperature Range

Outdoor Design Temperature (ODT)

The Outdoor Design Temperature (ODT) for a given location can be found in Appendix D. This temperature is based on a 10 year average and represents the highest sustained temperature that might be expected in normal summer conditions. The warmest month is July, and 2.5% of the time in July, the outdoor temperature may rise above the design temperature, but usually for only a short period of time. For Example-01 house located in Charlottetown, PEI, the outdoor design temperature (ODT) is 26° C (79°F).

Indoor Design Temperature (IDT)

The CSA F280-12 Standard requires the Indoor Design Temperature (IDT) used in heat gain calculations to be no higher than 75 °F (24 °C). Enter this amount on page 2 of the worksheet in Section B, Design Conditions, Heat Gain Column.

The process by which a house gains heat from the outdoors in summer is essentially the same process by which it loses heat to the outdoors in winter. The heat flows from areas of high temperature (outside) to areas of lower temperature (inside). However, for heat gain calculations, there are a number of additional considerations which are presented in the remainder of this section.

How Heat Gain Calculations Differ From Heat Loss Calculations

A heat gain calculation is performed to determine the cooling load for the house. Air conditioning units are sized by the "ton", with one ton being the equivalent of 12,000 Btu/h. A 'Btu' is a 'British Thermal Unit' and one Btu is the energy needed to raise the temperature of one pound of water one degree Fahrenheit.

The Heat Gain Calculation can be done in Btu/h or Watts. To convert from Btu/h to Watts, divide Btu/h by 3.412.

Solar Radiation Effect

When the sun shines on a wall or roof, it has the effect of creating a layer of air, next to the wall or roof that is at a higher temperature than the surrounding air temperature. This means that heat flow through the wall or roof may be driven by a temperature difference greater than the difference between the indoor and outdoor air temperature.

Mass Effect

A building assembly, such as a wall or roof, does not instantly heat up when the outside air next to it heats up but lags behind the air temperature due to the heat absorbed in raising the temperature of its mass. Since the outdoor air temperature in the summer varies over a significant range between day and night, the temperature of a building assembly not exposed directly to the sun in daytime could always be slightly behind the air temperature - cooler in the daytime, warmer at night. The heat gain

calculation process takes advantage of this by reducing the design temperature difference slightly. One can see that this effect tends to offset the "Solar Radiation Effect", so that even assemblies subject to direct sunlight may experience temperature differences lower than they would have been without the mass effect.

Solar Correction

As both the "Solar Radiation Effect" and the "Mass Effect" change the effective Heat Gain ΔT, both must be considered in the heat gain calculation. The following "Solar Correction" chart combines both effects and gives a solar correction temperature. Please note that the value changes according to the part of the building envelope that is being calculated.

The "Summer Mean Daily Temperature Range" can be found in Appendix D and has been noted in Section B, Design Conditions, Heat Gain Column, on page 2 of the worksheet.

Values for solar correction factors are based on whether the "Summer Mean Daily Temperature Range" is equal to or less than 25°F (14 °C) or greater than 25 °F (14 °C).

For a typical detached house which has walls with exposed walls facing in 3 or more directions, Solar Corrections Table for normal procedure can be used as provided below. (This is also provided in Appendix A, Table 10) In this table, solar corrections are applied based on different building assemblies only.

Interior partitions are interior walls between conditioned and unconditioned spaces, such as those between a house and a garage

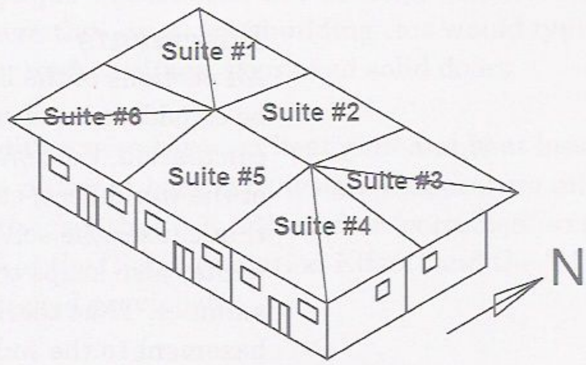
Building Assembly	Solar correction, SC (°F), by Summer Mean Daily Temperature Range	
	Up to and including 25°F	Over 25°F
Walls and doors	0	-6
Interior partitions and fully shaded exterior walls and doors	-6	-11
Roofs and top storey ceilings	+27	+22
Floors over non-conditioned rooms and ceilings under non-conditioned rooms	-6	-11

When calculating heat gain for row housing or condominiums with exposed walls facing in only 1 or 2 directions, a more detailed version of the Solar Correction Table needs to be used as provided below. (This is also provided in Appendix A, Table 11) In this table, different solar corrections are applied based on building assemblies and facing directions of exposed walls and doors.

Building Assembly	Orientation	Solar correction, SC (°F), by Summer Mean Daily Temperature Range: Up to and including 25°F	Solar correction, SC (°F), by Summer Mean Daily Temperature Range: Over 25°F
Walls, headers and doors	Factor for whole house calculation	0	-6
	North	-7	-12
	Northeast and Northwest	-1	-6
	East and West	+3	-2
	Southeast and Southwest	+1	-4
	South	-4	-9
Interior partitions and fully shaded exterior walls, headers and doors		-6	-11
Roofs and top storey ceilings		+27	+22
Floors over non-conditioned rooms and ceilings under non-conditioned rooms		-6	-11

Note: The normal procedure is to use the simplified "Solar Corrections Table – normal procedure", Appendix A, Table 10, which applies the same solar correction for walls and doors regardless of the direction they are facing.

Solar Corrections Example: Row Housing



The above figure shows the row housing layout, and a designer needs to calculate the heat gain for Suite #5.

Since suite #5 only has one facing direction of South for its exposed walls, the detailed version of the Solar Corrections Table for detailed procedure must be used.

If the building is in a location where the Summer Mean Daily Temperature Range is less than 25 °F, the solar correction of -4 °F needs to be applied for south facing walls in Suite #5.

Solar and Internal Gains (see Section 3.4 and section 3.15)

There are sources of heat in the house which would increase the required capacity of the cooling appliance. These include solar gains through windows, the heat given off by human bodies, the heat given off by appliances, lights and electrical plug loads. These were ignored in the heat loss calculations because they are not constant and the heating system must still be able to heat the house even when these gains are not present.

Latent Heat Gain

When a cooling system cools the air in a house, it also dehumidifies it - water vapour in the air condenses on the evaporator coil. In most cases the evaporator coil is mounted in the ductwork above the furnace where the refrigerant changes from a liquid to a gas and in this process removes heat from the air stream. This process makes the evaporator coil cold to the touch and below the dew point of the air in the duct. When water vapour condenses, it gives up a significant amount of heat. This is called "latent heat".

Latent heat must be taken into account in sizing the cooling system.

Basements

All portions of the building envelope **above-grade** have to be considered and calculated when doing a heat gain calculation. Portions of the building below-grade (Section 9 of the worksheet) can be ignored. The same "thermal inertia" that causes the soil to stay warmer than the outside air in winter also keeps the soil cooler than the outside air in summer. Thus there is some ongoing heat loss from the basement to the soil in summer. If we were to take this heat loss into account in our cooling load calculations, it would result in the required cooling capacity being lower. However, the CSA F280-12 standard specifically states that heat losses through below-grade walls and floors are not to be taken into account.

Heat Gain ΔT (HG ΔT)

The indoor design temperature for heat gain calculation is different than that used in heat loss calculation. If we kept our buildings as cool in summer as we are prepared to let them get in winter, they would seem too chilly compared to outdoors. Also a great deal more energy would be required in operating the cooling systems. On the other hand, if too high a value is used, occupants will not be satisfied with the amount of cooling provided.

The calculation for a given building is based on the temperature difference. This is determined as follows:

HG ΔT = ODT – IDT

Where:

ODT is the Outdoor Design Temperature

IDT is the Indoor Design Temperature

For Example-01: 79 °F – 75 °F = 4 °F
or 26 °C – 24 °C = 2 °C

Step i) Calculate HG ΔT and enter it in the space provided at the top left corner of page 3 of the worksheets

Heat Gain Through Opaque Materials

An opaque object is one in which light cannot transfer through the object. In a building this would typically include walls, roofs, ceilings, floors and solid doors.

> The effective R-value is the same for both heat loss and heat gain calculations

The differences between heat gain and heat loss calculations is the different basic ΔT (design temperature differences) and the fact that it is adjusted or "corrected" to take into account the "Solar Radiation Effect" and the "Mass Effect" mentioned previously.

Before proceeding with Heat Gain calculations, it must be noted that this chapter assumes that page 3, Column 1, structure and effective R-Value have already been inserted during Heat Loss calculations that are previous covered in Chapter 2 of this manual, and other Heat Loss calculations have been completed.

3.3 Gross Exposed Walls

- **Section 1, HRAI Residential Heat Loss and Gain Calculations, Page 3**

For Gross Exposed Wall Section 1 on Page 3 of the worksheet, the following considerations must be taken into account:

- **<u>The area of above-grade portions of the Basement wall</u>** must be entered in the Gross Exposed Wall section if they were not already done during the Heat Loss calculation (Note: they are not used for the Heat Loss calculations since the Foundation Thermal Load Calculator ("BasementHLR.xls") includes the above grade portion of basement walls in its calculations.)
- The term "fully shaded" on the Solar Corrections for Heat Gain Calculations chart, Table 10 and 11 in Appendix A (page A-12), refers to a section of wall or door which is 100% shaded by overhang or other structure. The overhang shading calculation can be made using the window shading calculation discussed later under the heading of "Shaded and Unshaded Areas".

- If different walls have the same construction, but have different Solar Corrections (e.g., one is fully shaded while the other is not), then the shaded area can be considered as a separate wall. The heat loss multiplier will be the same for both walls, but the heat gain multipliers of each wall will be different because of the different Solar Corrections.

Enter the structure designation and gross area for exposed walls in Section 1 of the worksheet. Columns for R-value (Column 1), Heat Loss Multiplier (Column 2), Solar Correction (Column 3) and Heat Gain Multiplier (Column 4) are grayed out in this section, since those values will be calculated later for Net Exposed Walls in Section 4, page 3 of the worksheet.

3.4 Windows, Glass Doors and Skylights

- **Section 2, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Heat Gain Through Transparent and Translucent Building Assemblies

The calculation procedure for heat gain through transparent and/or translucent materials differs from that for opaque materials. This is because the sun's rays can penetrate through glass and have a greater "heating" effect upon the inside of the building.

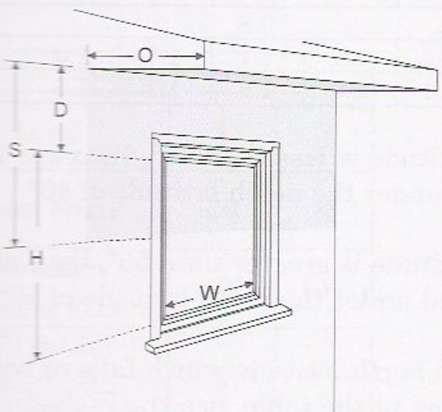
Whereas in heat loss calculations we ignored solar gains through glass, in heat gain calculations, we must take them into account.

If a window area is shaded by a roof overhang or permanent awning, it is obvious that the radiant effect of heating the air in the structure will be less than if it is not shaded. Therefore areas that are shaded must be calculated separately.

Calculation of Shaded and Unshaded Areas

The first step in the process is to go through a separate set of calculations to determine what portion of each window/glass area is shaded.

Note: Calculation of shaded and unshaded window area is only required for window areas that are facing in South, East / West or Southeast / Southwest direction. In other words, calculation of shaded areas is not required for North or Northeast / Northwest facing windows.



Step i)

S = F x O

Where:

S = Distance to shade line (calculated)

F = F-Shade Factor

O = Width of Overhang (measured)

Step ii)

SHADED AREA = (S - D) × W

Where:

W = Width of Window (measured)

S = Distance to Shade Line (from Step i) above)

D = Head Drop (measured)

Note A: SHADED AREA should not exceed H x W

Note B: If D is greater than S, then SHADED AREA is zero.

Special Note
As a simplification this manual suggests that H and W be measured from the rough frame opening. This allows the window dimensions from the heat loss calculations to also be used in the heat gain calculation.

Step iii)

UNSHADED AREA = H x W – SHADED AREA

Where:

H = Window Height (measured)

W = Width of Window (measured)

Shaded Area = Shaded Area as calculated above

The "F-Shade Factor" provides factors which are used in calculating shaded and unshaded areas. Because the sun is high in the sky in the summer, the lower the latitude, the higher it will be and hence the further down the wall the shade line will fall.

- The following F-Shade Factors are used regardless of the units (imperial or metric) in which the calculation is being done.

F Shade Factor							
Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

Note A: If north latitude is less than 40°, then use the F-shade factors listed under the north latitude of 40°

Note B: If north latitude is greater than 55°, then use the F-shade factors listed under the north latitude of 55°

Note C: For a given north latitude which falls in between the latitudes provided in the table, use the F-shade factor that is listed under the closest latitude. (e.g. If one needs to look up the F-shade factor for south facing direction at north latitude of 44°, then use the South F-shade factor of 2.0 listed under 45° North latitude.)

- Shaded areas will be recorded in Section 2 on the line labelled N & SH (north & shaded). This is done because the amount of light and heat penetrating through the shaded area closely approximates the light and heat penetrating through a North facing window area.
- Unshaded window areas are entered according to the direction the window actually faces.

Example:

If a South facing window having an area of 10 sq. ft. is 50% shaded, the areas on the worksheet would be entered as if there was a 5 sq. ft. North facing window, and a 5 sq. ft. South facing window.

Note A: Shading calculations, if required, would normally be done when the window areas were originally calculated for heat loss (i.e., the designer is performing a heat loss/gain analysis). If the heat gain calculation is done at a later stage, after heat loss calculations only have been performed, then areas entered for windows may have to be adjusted to account for shaded and un-shaded window areas.

The HRAI Window Shading Worksheet shown on the left side of this page, which comes as a page of HRAI Residential Heat Loss and Gain Calculations worksheet, provides a convenient method of tracking window shade analysis for specific rooms on each level. Perform the following based on Example-01:

Latitude = 46°		
Level	2	2
Room Name	LR	K
Direction Window Faces	SW	SW
W (ft / ~~m~~) Width of Window	9	10
H (ft / ~~m~~) Height of Window	4	4
A (ft^2 / ~~m^2~~) Total Window Area	36	40
O (ft / ~~m~~) Width of Overhang	3	3
F F-Shade Factor	1.1	1.1
S (ft / ~~m~~) S = F x O Shade Line	3.3	3.3
D (ft / ~~m~~) Drop	1	1
SA (ft^2 / ~~m^2~~) SA = (S-D) x W Shaded Area	20.7	23
UA (ft^2 / ~~m^2~~) UA = A – SA Unshaded Area	15.3	17

Step i) Find the latitude as provided in the design conditions based on the city. This is 46° in Example-01.

Step ii) Record the level.

Step iii) Record the room name for each level.

Step iv) Record the direction each window is facing.

Step v) Record the window width W. This is 9 ft for southwest facing windows in the Living Room (LR) and 10 ft for southewest facing windows in the Kitchen (K) in Example-01.

Step vi) Record the window height H. This is 4 ft for windows in the second level in Example-01.

Step vii) Calculate the window area:

$$A = W \times H$$

This is 36 ft^2 for the Living Room and 40 ft^2 for the Kitchen in Example-01.

Step viii) Record the overhang width; O. This is 3 ft in Example-01.

Step ix) Find the appropriate F-shade factor from Appendix A, Table 14 (the table is also provided at the bottom of HRAI Window Shading Worksheet). This is F = 1.1 for Example-01. (F-shade factor for Southeast / Southwest at latitude of 45° can be used, since the actual latitude of 46° is very close to 45°).

Step x) Calculate the shade line. This is 3.3 ft for Example-01.

Step xi) Record the overhang drop; D. This is D = 1 ft for Example-01.

Step xii) Calculate the shaded and unshaded areas and record them in the worksheet for future reference.

Calculation of Heat Gain through Windows

Heat gain through transparent building assemblies is a much more complex process than the simple flow of heat from a high temperature area to a low temperature area, since it does not only include conductive heat gain, but involves solar radiation heat gain as well.

The basic formula is:

Heat Gain = A x THGM

where:

A = area of the transparent portion of the building assembly

THGM = Transparent Assembly Heat Gain Multiplier for that portion of the building assembly, which needs to be calculated separately.

Transparent Assembly Heat Gain Multiplier

The transparent assembly heat gain multiplier (THGM) is defined as:

$$\mathbf{THGM} = \frac{\mathbf{HG\Delta T}}{\mathbf{R}} + (\mathbf{SHGC} \times \mathbf{SOLAR} \times \mathbf{ISF})$$

Where:

THGM = Transparent assembly heat gain multiplier (Btuh/ft² or W/m²)

HGΔT = Heat gain ΔT (°F or °C)

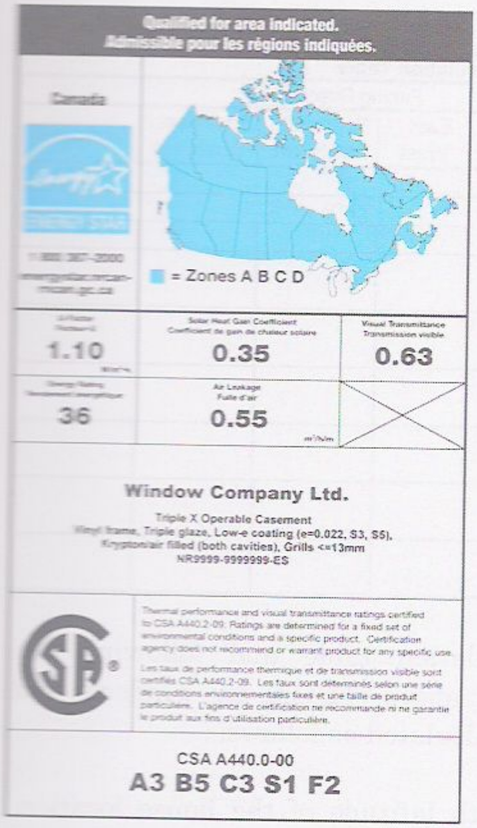
R = R or RSI-value of the window (ft². °F/ Btuh or m² .°C/W)

SHGC = solar heat gain coefficient of the window

SOLAR = solar radiation incident on the window (Btuh/ft² or W/m²)

ISF = internal shading factor for the window.

R-value for the window should have already been recorded in Column 1, page 3 of the worksheet if the heat loss calculation is completed prior to the heat gain calculation. Otherwise, they can be looked up from manufacturer's specification or from Tables 2 to 5, page A-6 to A-9 in Appendix A.



Solar heat gain coefficient (SHGC) defines the portion of the solar radiation which results in actual heat gain through the window. The solar heat gain coefficient (SHGC) can be looked up from the manufacturer's specification or from Tables 2 to 5, page A-6 to A-9 in Appendix A. Since solar heat gain coefficient (SHGC) is listed right next to the R-value of the window, it can be easily looked up and recorded when a designer is looking up window R-values from Tables in Appendix A. The SHGC value is dimensionless so it applies to both imperial and metric units.

Solar radiation incident on the window can be looked up from Table 13, page A-14 in Appendix A, and its value depends on the facing direction of a window and north latitude.

Internal shading factor (ISF) is used to account for the solar heat gain reduction from internal shades, and it can be looked up from Table 14, page A-14 in Appendix A. If no internal shading is present in the house, an ISF value of 1 will be used.

Note: In most cases, the applicable internal shading factor of 1 may be used based on no internal shading. This is because many residents prefer not to close curtains on windows during hot summer days. Also, using ISF value of 1 can be a conservative approach in calculating cooling load for a house.

For the case of Transparent Assembly Heat Gain Multiplier (THGM) calculation, the “Transparent Assembly Heat Gain Multiplier (THGM) Worksheet” is provided as the last page of HRAI Worksheet, which has the THGM calculation table as shown below:

THGM Calculation Table							
		Facing Direction					
		North & Shaded	South	East / West	Northeast / Northwest	Southeast / Southwest	Horizontal
North Latitude		°					
HGΔT		°F / °C					
Effective R-value							
#1	$\frac{HG\Delta T}{R}$						
#2	SHGC						
#3	SOLAR						
#4	ISF						
#5	(#2) × (#3) × (#4)						
#6	THGM=(#1) + (#5)						

Using the THGM calculation table and following the calculation steps outlined above, THGM for windows and other glass areas can be calculated as follows:

Step i) Look up north latitude of the house location, which has already been recorded in Section B, page 2 of the worksheet, and record it on the THGM table provided on the last page of the HRAI worksheet.

Step ii) Look up HG ΔT of the house location, which has already been recorded on top of page 3 of the worksheet, and record it on the THGM table provided on the last page of the HRAI worksheet.

Step iii) See window manufacturer's specification or Look up Table 2 to 5, page A-6 to A-9 in Appendix A to find the windows R-value and SHGC, and record R-value and SHGC on the THGM table.

Step iv) Divide HG ΔT by the R-value of the window to obtain (HG ΔT / R). Record the value in Row #1 of the table.

Step v) Based on north latitude noted and facing direction of window, look up solar radiation incident from Appendix A, Table 13, page A-14. (the table is also provided on the THGM table page of HRAI worksheet) Record the value in Row #3 of the THGM table.

Step vi) Look up Table 14, page A-14 in Appendix A to find the value of internal shading factor (ISF) for the window. Then, calculate (SHGC × SOLAR × ISF) and record in Row #5 of THGM table.

Step vii) Based on the formula provided in Row #6 of the THGM table, calculate the transparent assembly heat gain multiplier (THGM) and record the value on Column 4 of Section 2, page 3 of the worksheet

Example-01:

Calculate transparent heat gain multiplier (THGM) for unshaded, southeast and southwest facing windows.

Heat Gain ΔT is 4 °F.

Based on the window construction of double-glazed, operable aluminum, metal spacers, clear coatings, 1/2" argon filled spacing, the R-value of 1.14 and SHGC of 0.63 was obtained from Appendix A, page A-7, Table 3.

Southeast and southwest facing window at north latitude of 46° gives solar radiation incident of 98 Btu/h/ft² from Appendix A, page A-14, Table 13.

No presence of interior blinds has ISF value of 1.

The THGM for southeast / southwest facing windows is calculated in Row #6 of THGM table as shown below.

THGM Calculation Table							
		Facing Direction					
		North & Shaded	South	East / West	Northeast / Northwest	Southeast / Southwest	Horizontal
North Latitude		46 °					
HGΔT		4 °F					
Effective R-value						1.14	
#1	$\frac{HG\Delta T}{R}$					3.51	
#2	SHGC					0.63	
#3	SOLAR					98	
#4	ISF					1	
#5	(#2) × (#3) × (#4)					61.74	
#6	THGM=(#1) + (#5)					65.25	

The calculated THGM value also gets transferred on the designated lines of Column 4, Section 2, page 3 of the worksheet.

HRAI Residential Heat Loss and Heat Gain Calculations							Page 3 of ___		
		HL ΔT =	76	HG ΔT =	4		P_E	LVL	
							H	RM	
COMPONENTS	STRUCTURE	EFFECTIVE R-VALUE Col 1	$\frac{HL\Delta T}{R}$ Col 2	SC Col 3	$\frac{(HG\Delta T+SC)}{R}$ Col 4		A_F Area	HEAT LOSS	HEAT GAIN
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH				THGM				
	S				THGM				
	E/W				THGM				
	NE/NW				THGM				
	SE/SW	1.14	66.67		THGM	65.25			
	HOR				THGM				

Note A: If you do not know whether or not a window will have internal shading, you should assume that it will not.

Note B: If you are designing a cooling system for a builder's house model without knowing which direction it will be oriented, you should assume the orientation that results in the wall with the most glazing facing southwest.

Note C: For Section 2, Windows, Glass Doors and Skylights, **Transparent Assembly Heat Gain Multiplier (THGM)** is used instead of the Heat Gain Multiplier formula used in other sections.

3.5 Exposed Doors

- **Section 3, HRAI Residential Heat Loss and Heat Gain Calculations, page 3 of the Worksheet**

Calculate the Heat Gain Multiplier

The heat gain multiplier is defined as: $\frac{(HG\Delta T+SC)}{R}$

Step i) Using the information on the Mean Summer Daily Temperature Range noted in Section B, Design Conditions, page 2 of the worksheet, turn to the Solar Corrections for Heat Gain Calculations Table on page A-12 in Appendix A, and select the appropriate Solar Correction for doors. Enter this on the designated line in Column 3, Exposed Doors, Section 3, page 3 of the worksheet.

Step ii) The Heat Gain Multiplier in Column 4, page 3 of the worksheet is obtained by:

a) Using the HGΔT from the top left corner on page 3 of the worksheet, add the Solar Correction selected back in Step i).

b) Divide the sum of the HG ΔT and the Solar Correction (SC) by the R-Value noted in Column 1, page 3 of the worksheet.

c) Enter this calculated amount on the designated line under Heat Gain Multiplier, Column 4 of Other Exposed Doors, Section 3, page 3 of the worksheet.

Note A: It is possible that when the Solar Correction is used, the results can be negative or zero. If this is the case, there is no significant Heat Gain through this component and use the value of zero for the Heat Gain Multiplier.

3.6 Net Exposed Walls

- **Section 4, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Calculate the Heat Gain Multiplier

The heat gain multiplier is defined as: $\frac{(HG\Delta T+SC)}{R}$

Step i) Using the information on the Mean Summer Daily Temperature Range noted in Section B, Design Conditions, page 2 of the worksheet, turn to the Solar Corrections for Heat Gain Calculations Table on page A-12 in Appendix A, and select the appropriate Solar Correction for walls. Enter this on the designated line in Column 3, Net Exposed Walls, Section 4, page 3 of the worksheet.

Step ii) The Heat Gain Multiplier in Column 4, page 3 of the worksheet is obtained by:

a) Using the HG ΔT from the top left corner on page 3 of the worksheet, add the Solar Correction selected back in Step i).

b) Divide the sum of the HG ΔT and the Solar Correction (SC) by the R-Value noted in Column 1, page 3 of the worksheet.

c) Enter this calculated amount on the designated line under Heat Gain Multiplier, Column 4 of Net Exposed Walls, Section 4, page 3 of the worksheet.

3.7 Header Areas

- **Section 5, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Header areas should be included as part of the room directly below the header area.

Calculate the Heat Gain Multiplier

The heat gain multiplier is defined as: $\frac{(HG\Delta T+SC)}{R}$

Step i) Using the information on the Mean Summer Daily Temperature Range noted in Section B, Design Conditions, page 2 of the worksheet, turn to the Solar Corrections for Heat Gain Calculations Table on page A-12 in Appendix A, and select the appropriate Solar Correction for Header Areas (Walls). Enter this on the designated line in Column 3, Header Areas, Section 5, page 3 of the worksheet.

Step ii) The Heat Gain Multiplier in Column 4, page 3 of the worksheet is obtained by:

a) Using the HG ΔT from the top left corner on page 3 of the worksheet, add the Solar Correction selected back in Step i).

b) Divide the sum of the HG ΔT and the Solar Correction (SC) by the R-Value noted in Column 1, page 3 of the worksheet.

c) Enter this calculated amount on the designated line under Heat Gain Multiplier, Column 4 , Header Areas, Section 5, page 3 of the worksheet.

3.8 Exposed Ceilings

- **Section 6, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Calculate the Heat Gain Multiplier

The heat gain multiplier is defined as: $\frac{(HG\Delta T+SC)}{R}$

Step i) Using the information on the Mean Summer Daily Temperature Range noted in Section B, Design Conditions, page 2 of the worksheet, turn to the Solar Corrections for Heat Gain Calculations Table on page A-12 in Appendix A, and select the appropriate Solar Correction for exposed ceilings. Enter this on the designated line in Column 3, Exposed Ceilings, Section 6, page 3 of the worksheet.

Step ii) The Heat Gain Multiplier in Column 4, page 3 of the worksheet is obtained by:

a) Using the HG ΔT from the top left corner on page 3 of the worksheet, add the Solar Correction selected back in Step i).

b) Divide the sum of the HG ΔT and the Solar Correction (SC) by the R-Value noted in Column 1, page 3 of the worksheet.

c) Enter this calculated amount on the designated line under Heat Gain Multiplier, Column 4 of Exposed Ceilings, Section 6, page 3 of the worksheet.

Note: Solar Corrections (SC) for Ceilings is considerably different from SC values for other components (e.g., Ceiling SC can be +27 °F or +22 °F).

3.9 Exposed Floors

- **Section 7, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

The floor in a given room must be exposed to a temperature difference before this area of the worksheet is used.

The calculations for Exposed Floors, Section 7, Columns 3 and 4, follow the same procedure as Ceilings, Section 6, Columns 3 and 4, once it is determined that Floors are exposed to a temperature difference.

3.10 Other

- **Section 8, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

This section is used to provide extra space as required. An example would be when a particular house had 3 types of doors. As there are only 2 lines provided in Section 3 (Exposed Doors), the 3rd door could be put into Section 8.

3.11 Foundation Conductive Heat Loss

- **Section 9, HRAI Residential Heat Loss and Gain Calculations Worksheet, page 3**

Foundation conductive heat loss is not used in heat gain calculations.

3.12 Room Section of Worksheet

- Before proceeding to Section 10 of the worksheet, the Heat Gain for each of the components is calculated (other than Gross Exposed Walls, Section 1, and Below Grade Heat Loss, Section 9) in each room.

Step i) Using the formula below enter the Heat Gain amount in third column for each room:

For Opaque Assemblies (Section 3 to 8):

Heat Gain = Heat Gain Multiplier (Col. 4) x Area

For Transparent Assemblies (Section 2):

Heat Gain = Transparent Assembly Heat Gain Multiplier (Col. 4) x Area

Note: Areas used for Heat Gain calculations are the same areas that were used to calculate Heat Loss with the exception of the above grade portions of a Basement if they were not done at the time of Heat Loss Calculation.

3.13 Total Conductive Heat Gain

- **Section 10, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Step i) Add heat gain amounts from Sections 2 to 8, for each room.

Note: All rooms in all levels of the building must be completed into this section of the worksheet (Total Conductive Heat Gain) before proceeding with the completion of the remainder of the worksheet.

Step ii) Building Total Conductive Heat Gain (Section 10) is the sum of all room conductive heat gains (Section 10, each Room) in a building. Enter this amount in the space provided on the left side of Section 10, page 3 of the worksheet besides the heading "Total Heat Gain".

		LVL 1	LVL 2	LVL 3	LVL 4
10. TOTAL CONDUCTIVE	TOTAL HEAT LOSS				
	TOTAL HEAT GAIN				

Note: It should be noted that although the numbers entered in Section 10 are referred as "Total Conductive Heat Gain", this heat gain calculated in Section 10 actually includes radiant heat gain through transparent assemblies. Technically, "Total conductive and radiant heat gain" would be the right term to describe numbers entered in Section 10. However, for the sake of simplicity, "Total conductive and radiant heat gain" will be simply referred to as "Total conductive heat gain" in this manual.

3.14 Air Change Heat Gain

In any building there is going to be a certain amount of air leaking across the building envelope. This air must be accounted for when doing a calculation as it is cool air being lost, and replaced by warmer outside air which has to be cooled.

Air Change

Air change is the continuous exchange of air between every building and the outdoors. The air change is the result of two separate processes: *ventilation* and *air leakage.*

Ventilation

Ventilation is a controlled air change. It can be provided by bathroom and kitchen exhaust fans, dryer vents and any other mechanical devices that expel air from, or deliver air into the structure.

Air Leakage

Air leakage is an uncontrolled air change, and includes both *infiltration* and *exfiltration*, as air flows through cracks, structural joints, gaps around window frames, and many other unintentional openings in the building envelope. *Infiltration* refers to the flow of air from the outdoors into the building enclosure. *Exfiltration* refers to the flow of air from inside of the building to the outdoors.

Air Leakage Heat Gain Calculations are completed in three steps:

Step i) Calculation of Building Air Leakage Heat Gain

Step ii) Calculation of the Air Leakage Heat Gain Multiplier

Step iii) Calculation of Air Leakage Heat Gain for each room

Note: Space and formula have been placed on the "Formula Sheet" for calculating the Building Air Leakage Heat Loss and Air Leakage Heat Gain Multiplier.

A significant change to the 2012 edition of the CSA F280 Standard is the inclusion of a link to a Microsoft Excel® spreadsheet that calculates the envelope air leakage rate as part of the heat gain due to air leakage.

Note A: Use of the AIM2.xls spreadsheet is required in order to complete Step i). The output from the spreadsheet is the envelope air leakage rate for heating which is required in the formula to calculate the Heat Gain Due to Air Leakage for the building.

1) Calculation of Heat Gain Due to Air Leakage

The calculation of the heat gain due to air leakage is calculated separately from the heat gain due to mechanical ventilation.

$$\mathbf{HG_{leak} = B \times LR_{airc} \times V_b \times HG\Delta T}$$

Where:

HG_{leak} = Building air leakage heat gain (Btuh or W)

B = 0.018 for Imperial <u>OR</u> 0.33 for Metric units

LR_{airc} = Envelope air leakage rate for cooling (output from the Envelope Air Leakage Calculator Spreadsheet)

V_b = Building volume (ft³ or m³) as noted in Section B, page 2 of the worksheet

HGΔT = Heat gain ΔT from top of page 3 of the worksheet (°F or °C)

The calculation of the design temperature difference, HGΔT, has already been covered earlier in this chapter, and the

volume of the building is already determined and entered in Section B, page 2 of the worksheet.

Envelope Air Leakage Rate Calculator

CSA F280-12 includes a link to a Microsoft Excel spreadsheet "AIM2.xls" that can be used to calculate some of the factors needed for determining the air leakage heat gain of the building.

The instruction on using "AIM2.xls" is already covered in "Chapter 2 – Heat Loss Calculations" under "Section 2.14: Air Change Heat Loss". It should be noted that this chapter assumes that the Air Leakage Rate calculation is already completed and the Envelope Air Leakage Rate for Cooling (LR_{airc}) is obtained from previous heat loss calculations. In Example-01, the Envelope Air Leakage Rate for Cooling (LR_{airc}) is calculated as 0.099 ACH/h

1.1) Heat Gain Due to Air Leakage

Once the Cooling Air Leakage (LR_{airc}) is obtained from the output of the spreadsheet, it is used in the formula for Building Air Leakage Heat Gain (HG_{leak}) which is given on the Formula Sheet of the HRAI worksheet.

For Example-01, Building Air Leakage Heat Gain is calculated as follows:

BUILDING AIR LEAKAGE HEAT GAIN
$HG_{leak} = B \times LR_{airc} \times Vb \times HG\Delta T$ B (M) = 0.33 B (I) = 0.018
$= \underline{0.018} \times \underline{0.099} \times \underline{15744} \times \underline{4} = \boxed{112}$

This value should be recorded as a whole number to the nearest Btu/h or W.

1.2) *Air Leakage Heat Gain Multiplier*

The Air Leakage Heat Gain Multiplier is required to determine the heat gain due to air leakage for each room. Once the Building Air Leakage Heat Gain has been calculated, it is used in the formula below to calculate the air leakage heat gain multiplier.

$$\textbf{Multiplier} = \frac{\textbf{HG}_{\textbf{leak}}}{\textbf{Building Conductive Heat Gain}}$$

Where:

Multiplier = air leakage heat gain multiplier

HG$_{leak}$ = building air leakage heat gain in Btu/h or Watts (calculated previously)

Building Conductive Heat Gain

= sum of total conductive heat gains for all rooms in the building which should have been already entered in Section 10, page 3 of the worksheet

Unlike air leakage heat loss multipliers, air leakage heat gain multipliers are unaffected by level factors. Thus, a single air leakage heat gain multiplier is applied to rooms at all levels in the building.

When the Air Leakage Heat Gain Multiplier has been calculated on the HRAI Air Leakage / Ventilation Calculation Formula Sheet, enter it into the space provided on the left side, Section 11, page 3 of the worksheet.

For Example-01, air leakage heat gain multiplier is calculated as follows:

$$\text{Air Leakage Heat Gain Multiplier} = \frac{HG_{leak}}{\text{Building Conductive Heat Gain}} = \frac{112}{8523} = \boxed{0.0131}$$

11. AIR LEAKAGE					
	HEAT LOSS MULTIPLIER				
	HEAT GAIN MULTIPLIER	0.0131			

Note A: To ensure the accuracy, make sure that the air leakage heat gain multiplier has at least four decimal digits.

1.3) Air Leakage Heat Gain for Each Room

To calculate the Air Leakage Heat Gain for a room, multiply the Air Leakage Heat Gain Multiplier (provided on the left side, Section 11, page 3 of the worksheet) by Total Conductive Heat Gain (provided on Section 10, page 3 of the worksheet) for that room.

Room Air Leakage HG

= Room Conductive HG × Air Leakage HG Multiplier

The Air Leakage Heat Gain for a room is then entered in Section 11 in the Heat Gain column for that room. This step must be repeated for each room in the house.

2) Calculation of Heat Gain Due to Continuous Mechanical Ventilation

For purposes of a ventilation heat gain calculation, only heat gains caused by a mechanical ventilation system will be considered.

Regardless of the type of cooling system that is being used, the size of the equipment must be able to handle the added load of ventilation. It is entirely separate from the air leakage heat gain.

All new construction must have ventilation load included in the calculation of heat gain for the house as all building codes in Canada require a minimum rate of continuous mechanical ventilation.

If it is to be a cooling system replacement where no mechanical ventilation system exists or is to be installed, there is no need for the ventilation calculation.

In cases where the ventilation system incorporates some type of heat recovery capacity, such as a heat recovery ventilator or an energy recovery ventilator (HRV/ERV), no allowance is made for the heat removed.

The heat gain due to mechanical ventilation is based on the continuous or principal ventilation capacity rate (PVC) as used in building codes such as the National Building Code of Canada (NBC), the Ontario Building Code (OBC) and the British Columbia Building Code (BCBC).

Alternately, CAN/CSA-F326 may be used to obtain the low continuous ventilation rate (in this case, 40% to 60%) of the Minimum Ventilation Capacity (MVC) as stipulated in the standard. This can be used as the "principal ventilation" rate for calculation purposes.

The methodology used to determine the heat gain due to continuous mechanical ventilation is dependent upon the type of ventilation system. This includes the following:

1) Exhaust only system
2) Direct ducted system
3) Central forced air system

In the first type of mechanical ventilation system, the exhaust only system, the building ventilation heat gain gets calculated based on the Principal Ventilation Capacity (PVC) rate without assigning any allowance for ERV/HRV equipment, and this building ventilation heat gain gets apportioned to each room based on conductive heat gain for each room.

For the second type of mechanical ventilation system, the direct ducted system, a supply air fan and separate duct system is used to distribute the air to specific rooms in the home. To correctly apportion direct ducted ventilation systems, the Building Ventilation Heat Gain is calculated at the Principal Ventilation Capacity (PVC) rate without assigning any allowance for ERV/HRV equipment. This Building Ventilation Heat Gain is then divided equally by the total number of supply outlets, adding these loads to the rooms where the supply outlets are located. In the case of Provincial Codes, ventilation supply air must be distributed as follows:

- NBC: Each bedroom, any storey (including basements and heated crawlspaces) without a bedroom, and if there is no storey without a bedroom, to the principal living area.
- OBC: Each bedroom, to any storey without a bedroom and, if there is no storey without a bedroom, to the principal living area.
- BCBC: Each bedroom and one common area if through-the-wall inlets are used, and into each bedroom, each floor level without a bedroom, and each heated crawlspace if a direct ducted HRV/ERV is used.

If a CAN/CSA-F326 ventilation system design is used, it must have supply air distributed to all habitable rooms, except those with exhaust from the room, at rates specified

For a direct ducted system, PVC (principal ventilation capacity) may be apportioned equally to each applicable room as follows:

$$Qvr = \frac{PVC}{\text{\# of rooms with supply outlets}}$$

Where:
Qvr = Room Ventilation Rate

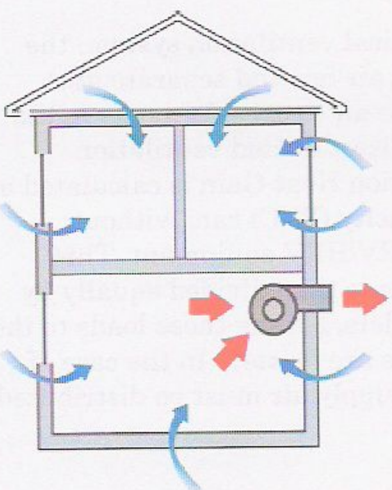
in the Standard. The rates are 20 cfm supply to master bedrooms and basement areas greater than 2/3 of the total basement area, and 10 cfm supply to all other habitable rooms. Therefore the ventilation supply air heating/cooling loads should be apportioned based on the proportion of total ventilation air flows delivered to each room.

For the last type of mechanical ventilation system, the Central Forced Air System, the supply air is supplied to the return air duct of the forced air system and is then distributed to all rooms in proportion to the heating loads. In this case Building Ventilation Heat Gain is calculated at the Principal Ventilation Capacity (PVC) rate without assigning any allowance for ERV/HRV equipment and this load is added directly to the capacity of the cooling appliance, without having ventilation cooling load distributed to rooms.

The next sections of the manual show the detailed procedures used to apportion the ventilation heat gain.

2.1) Exhaust Only Ventilation System

- **Section 12a, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**



Exhaust only system

Heat gain due to an exhaust only ventilation system is calculated in the following steps:

Step i) The building heat gain associated with the principal or continuous ventilation must be calculated first as provided in the formula sheet and below:

VENTILATION HEAT GAIN

C (M) = 1.2
C (I) = 1.08

$$HG_{bvent} = C \times PVC \times HG\Delta T \times (1 - ATRE)$$

= _____ x _____ x _____ x _____ = $\boxed{}$

$$\mathbf{HG_{bvent} = C \times PVC \times HG\Delta T \times (1 - ATRE)}$$

Where:

$\mathbf{HG_{bvent}}$ = Building ventilation heat gain (Btu/h or W)

C = 1.08 for Imperial <u>OR</u> 1.2 for Metric units

PVC = Principal or continuous ventilation rate (CFM or L/s)

Note A: Ideally the PVC is provided by the Ventilation system Design. If it is not available, then the PVC may be determined by the designer in accordance with local building code requirements or 40% to 60% of Maximum Ventilation Capacity (MVC) if CAN/CSA-F326 is used (see Appendix A, Table 15a, 15b or 15c).

HG∆T = Heat gain ∆T from top of page 3 of the worksheet (°F or °C)

ATRE = Adjusted total recovery efficiency of the HRV/ERV looked up from HVI's directory

Note B: Use ATRE = 0 for an exhaust only system as no HRV/ERV is being used

Note C: Use ATRE = 0, if ATRE data for HRV/ERV cooling performance is not available in HVI's certified-product directory.

> Note about ATRE:
>
> Adjusted Total Recovery Efficiency (ATRE) can be looked up from Home Ventilating Institute's (HVI) certified-product directory under HRV/ERV's cooling mode performance data.

Step ii) Calculate the ventilation heat gain multiplier using the following formula provided on the formula sheet below:

Case #1: Exhaust Only System (Section 12a)

$$\text{Multiplier} = \frac{HG_{bv\,ent}}{\text{Building Conductive Heat Gain}}$$

$$\text{Multiplier} = \frac{\qquad}{\qquad} = \boxed{\qquad}$$

$HG_{rv\,ent}$ = Multiplier x Room Conductive Heat Gain

Multiplier
= HG_{bvent} ÷ Building Conductive Heat Gain

Where:

Multiplier = Building ventilation heat gain multiplier for exhaust only system

HG_{bvent} = Building ventilation heat gain, calculated previously in Step i) (Btu/h or W)

Building Conductive Heat Gain
= Total conductive heat gain for the whole building, recorded in Section 10, page 3 of the worksheet (Btu/h/W)

Once the ventilation heat gain multiplier is calculated for the exhaust only system, transfer the number to Section 12a, page 3 of the worksheet, beside the heading "Heat Gain Multiplier"

12a. VENTILATION:	HEAT LOSS MULTIPLIER				
EXHAUST ONLY	HEAT GAIN MULTIPLIER				

Step iii) Calculate the ventilation heat gain assigned to each room, using the ventilation heat gain multiplier calculated in Step ii) using the formula below.

HG_{rvent}
= Multiplier × Room Conductive Heat Gain

HG_{rvent} = Room ventilation heat gain (Btu/h or W)

Multiplier = Ventilation heat gain multiplier recorded in Section 12a, page 3 of the work sheet

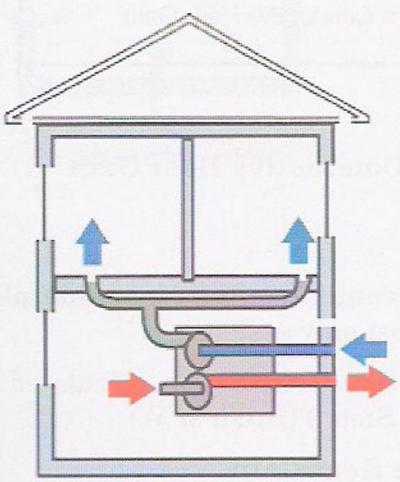
Room Conductive Heat Loss = Total conductive heat gain for the room recorded in Section 10 of the worksheet (Btu/h or W)

This step must be repeated for each room in the house.

2.2) Direct Ducted System

- **Section 12b, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

If a separate duct system is used for the ventilation air, and the flow rate to each room is known, there are two steps in the process of calculating ventilation heat gain.



Direct ducted system

Step i) Calculate the ventilation heat gain multiplier for Direct Ducted System in the space provided on the formula sheet below.

Case #2: Direct Ducted System (Section 12b)

C (M) = 1.2
C (I) = 1.08

Multiplier = C x HGΔT x (1 - ATRE)

Multiplier = ______ x ______ x ______ = $\boxed{}$

Q_{vr} = Room Ventilation Rate
HG_{rvent} = Multiplier x Q_{vr}

Multiplier = C × HGΔT × (1 – ATRE)

Where:

Multiplier = Ventilation heat gain multiplier for direct ducted system

C = 1.08 for Imperial OR1.2 for Metric units

HGΔT = heat gain ΔT from top of page 3 of the worksheet (ºF or ºC)

ATRE = Adjusted total recovery efficiency of the HRV/ERV looked up from HVI's directory

Once the ventilation heat gain multiplier is calculated for the direct ducted system, transfer the multiplier to Section 12b, page 3 of the worksheet, beside the heading "Heat Gain Multiplier".

12b. VENTILATION: DIRECT DUCTED SYSTEM	HEAT LOSS MULTIPLIER	
	HEAT GAIN MULTIPLIER	

For a direct ducted system, PVC (principal ventilation capacity) may be apportioned equally to each applicable room as follows:

$$Qvr = \frac{PVC}{\text{\# of rooms with supply outlets}}$$

Where:
Qvr = Room Ventilation Rate

Step ii) Apportion the ventilation flow rate to individual rooms (Q_{vr}) in accordance with the ventilation design (e.g. NBC/OBC/BCBC or CAN/CSA-F326) as explained previously in "Calculation of Heat Gain Due to Continuous Mechanical Ventilation". Enter the number in Section 12b of the worksheet under the heading "Q_{vr}".

Qvr		

Step iii) Calculate the ventilation heat gain assigned to each room, using the ventilation heat gain multipliers calculated in Step i) using the formula below.

$$\mathbf{HG_{rvent} = Multiplier \times Q_{vr}}$$

Where:

$\mathbf{HG_{rvent}}$ = Room Ventilation Heat Gain (Btu/h or W)

Multiplier = ventilation heat gain multipliers recorded in Section 12b, page 3 of the work sheet

Qvr = ventilation flow rate for the room calculated in previous Step ii), (CFM or L/s) recorded in Section 12b of the worksheet

Once the ventilation heat gain for each room has been calculated, enter each value in Section 12b of the HRAI Residential Heat Loss and Heat Gain Calculations worksheet.

2.3) Central Forced Air System

- **Section 22, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Heat gain due to supply to a central forced system is calculated using the formula below:

VENTILATION HEAT GAIN
$HG_{bvent} = C \times \; PVC \; \times \; HG\Delta T \; \times (1 - ATRE)$ C (M) = 1.2, C (I) = 1.08
= ____ x ____ x ____ x ____ = [ ]

$$HG_{bvent} = C \times PVC \times HG\Delta T \times (1 - ATRE)$$

Where:

HG_{bvent} = Building ventilation heat gain (Btu/h or W)

C = 1.08 for Imperial OR 1.2 for Metric units

PVC = Principal or continuous ventilation rate (CFM or L/s)

Note A: Ideally the PVC is provided by the Ventilation system Design. If it is not available then the PVC may be determined by the designer in accordance with local building code requirements or 40% to 60% of Maximum Ventilation Capacity (MVC) if CAN/CSA-F326 is used (see Appendix A, Table 15a, 15b or 15c).

$HG\Delta T$ = Heat gain ΔT from top of page 3 of the worksheet (°F or °C)

ATRE = Adjusted total recovery efficiency of the HRV/ERV looked up from HVI's directory

The above noted Building Ventilation Heat Gain, HG_{bvent}, only considers the sensible component of heat gain only. In order to include latent component of heat gain, HG_{bvent} will have to be **multiplied by a factor of 1.3** as provided below:

Case #3: Central Forced Air System (Section 22)
HG_{bvent} x 1.3 = [ ] x 1.3 = [ ]
(enter in Section 22)

After HG_{bvent} **gets multiplied by 1.3**, enter the result in Section 22, Page 3 of the HRAI Residential Heat Loss and Heat Gain Calculations worksheet. This is the sum of sensible and latent heat gain for the central forced air ventilation system.

3.15 Internal Heat Gain (People, Appliances & Lights)

- **Section 13, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

People

When doing heat gain calculations, other sources of heat cannot be ignored. As human occupants give off energy in the form of heat, there is an additional load for the cooling equipment.

The calculation is simply to add 239 Btu/h (70 W) of sensible heat gain for each person who is normally expected to occupy the house at peak load conditions. Latent heat gain due to people is captured later when heat gain is multiplied by 1.3.

If the number of people occupying the house is not known, the calculation is then based on the number of bedrooms plus one. In other words, a three bedroom house would be calculated as if there were four occupants. The load shall be applied to the rooms that are most likely to be occupied at the time of peak cooling requirements. Since the highest cooling load is typically in the afternoon it would be such as Family Room, Living Room or Dining Room. The designer has some discretion and should consider the Appliance gains as well.

Using Example-01:

\# of occupants = 3 occupants (2 bedrooms +1).

Internal heat gain due to people:

HG_{sp} = 3 occupants x 239 Btu/h per occ. = 717 Btu/h

Heat Gains due to Lights, Appliances, and Electrical Plug Loads

In addition to humans, appliances, such as refrigerators, lights and plug loads continually give off heat which has to be added to the cooling load.

A heat gain of 1.27 Btu/h per ft ^{2} (4 W/m^2) of gross floor area (but not lower than 2730 Btu/h or 800W), shall be applied to one or more electric peak load rooms that are present in the building (e.g. family, living, and/or kitchen).

Example-01:

Internal heat gain due to lights, appliances and electrical plug loads

$$\begin{aligned} \mathbf{HG_{lae}} &= \text{Total Building Floor Area x 1.27 Btu/h/ft}^2 \\ &= 1536 \times 1.27 \\ &= 1951 \text{ Btu/h} \end{aligned}$$

Since $\mathbf{HG_{lae}}$ = 1951 < 2730 Btu/h, use the plug load heat gain of 2730 Btu/h for the whole building

Assign and apportion the internal heat gain due to people and plug load for applicable rooms, and enter the number in Section 13, page 3 of the worksheet.

Example-01:

The house has one thermal peak load room (Living Room) and two electric peak load rooms (Living Room and Kitchen).

$\mathbf{HG_{sp}}$ = 717 Btu/h (to be assigned to Living Room)

$\mathbf{HG_{lae}}$ = 2730 Btu/h (to be apportioned to Living Room and Kitchen at 1365 Btu/h each)

Living Room Internal HG = 717 + 1365 = **2082 Btu/h**

Kitchen Internal HG = **1365 Btu/h**

3.16 Net Load

- **Section 14, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add room Total Conductive Heat Gain (Section 10), room Air Leakage Heat Gain (Section 11), room Ventilation Heat Gain (Section 12a or 12b, if applicable), and room Internal Heat Gain (Section 13). Enter amount calculated in Section 14 for each room. This calculation must be made for each room.

3.17 Duct/Pipe through Unconditioned Spaces

- **Section 15, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

When air is conveyed through a duct system in an unconditioned space, there will be a temperature difference between the surrounding air and the air in the duct. This causes a heat gain.

The extra cooling that has to be added by the cooling system is calculated by the appropriate duct heat Gain multiplier from the Duct Multipliers Table 8 in Appendix A, page A-11.

The formula for calculating duct heat gain is as follows:

Duct Heat Gain = Net Loads (heat gain) (Section 14) x Duct Heat Gain Multiplier

Enter this amount in Section 15 of the worksheet.

3.18 Total Heat Loss for Each Room

- **Section 16, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in Heat Gain Calculations.

3.19 Total Heat Gain for Each Room

- **Section 17, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Up to this point in heat gain calculations, we have only considered Sensible Heat Gains. Another type of heat gain takes place when moisture in the air condenses on the evaporator coil. To compensate for heat release during the condensation process (Latent Heat), 30% must be added to the total calculated sensible heat gains.

Add Section 14 to Section 15, and then **multiply by 1.3**. Calculate and enter this amount in Section 17 of the worksheet for each room.

This calculation must be made for every room to be conditioned.

3.20 Sub Total Heat Loss (Building)

- **Section 18, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in Heat Gain Calculations.

3.21 Central Forced Air Ventilation Heat Loss

- **Section 19, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in Heat Gain Calculations.

3.22 Total Heat Loss (Building)

- **Section 20, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Not used in Heat Gain Calculations.

3.23 Sub Total Heat Gain (Building)

- **Section 21 HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add up Total Heat Gain for Each Room (Section 17). Enter the amount in Section 21.

3.24 Central Forced Air Ventilation Heat Gain

- **Section 22, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

For central forced air ventilation system heat gain, **multiply the building ventilation heat gain (HL_{bvent}) by 1.3** to include and compensate for latent heat gain (30% of the sensible heat gain) in cooling equipment sizing. Enter the amount in Section 22.

For all other ventilation systems (Exhaust only system and Direct ducted system), leave Section 22 blank.

3.25 Total Heat Gain (Building)

- **Section 23, HRAI Residential Heat Loss and Heat Gain Calculations, page 3**

Add up Building Sub Total Heat Gain (Section 21) and Central Forced Air Ventilation Heat Gain (Section 22, if applicable). Enter the amount in Section 23.

3.26 Cooling System Capacity

Gross over sizing will cause excessive over-cycling with long off periods and insufficient Humidity Control.

a) Where the cooling system is being added to an existing heating system, its capacity, in Watts, need not exceed 18 times the air handling capacity of the heating system in liters per second, or its capacity in Btu/h need not exceed 29 times the air handling capacity of the heating system in cubic feet per minute. This means that the cooling system may be undersized so that the air handling capacity of the furnace is large enough to meet the air flow requirements of the cooling system. It should be noted that this provision only applies to situations where a cooling system is being added to an existing furnace. Under some circumstances, it would be in the consumer's best interest to replace the furnace with one having a larger air handling capacity.

b) Except as provided in (a) above, the cooling system capacity shall not be less than 80% of the calculated heat gain, and in no case shall it be less than the calculated heat gain, minus 1,800 W (6,143 Btu/h).

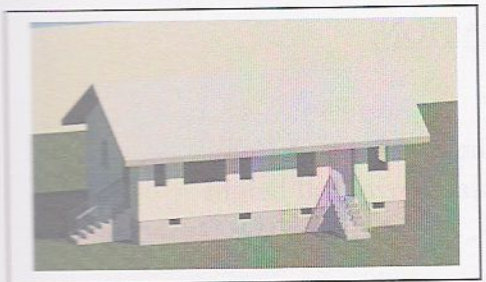
c) Except for ground-source and water-source heat pumps used for cooling, the cooling system capacity shall not exceed 125% of the calculated heat gain as determined in the cooling calculation.

d) While the CSA F280-12 standard does not include the following comment, it is generally accepted that oversizing in excess of 125% is permitted in certain situations. A calculated heat gain of 4,190 W (14,300 Btu/h) or less, or between 5,274 W (18,000 Btu/h) and 5,596 W (19,100 Btu/h) will demand oversizing in excess of 125%. This oversizing of the equipment should not cause comfort problems for the occupants.

3.27 Example Heat Gain Calculation

Example-01

SPECIFICATIONS



LOCATION:
This detached house was built in Charlottetown, Prince Edward Island in 2014. The foundation is a basement. There is one storey (Level 2) above grade. Arrange rooms in the following order on the worksheet:

Foundation (Level 1):
OFF (Office), RR (Rec Room), M (Mechanical)

Main Floor (Level 2):
BR2 (Bedroom-2), MB (Master Bedroom), LR (Living Room), K (Kitchen)

DESIGN CONDITIONS:
Winter indoor design temperature 72 °F.
Summer indoor design temperature 75 °F.
Inside conditions apply to all areas of the house

Foundation level (Level 1) ceiling height is 8'.
For the second level (Level 2), the highest ceiling height is 14' and the lowest ceiling height is 9'.
Header height is 12".
Basement wall extends 4' below grade.

SITE CONDITION:
Soil conductivity is high.
Water table is normal.

VENTILATION REQUIREMENTS:
The house will be considered new construction in which a HRV is ducted to return air of central forced air system. Therefore, a ventilation calculation in accordance with CSA F326 or local building code will be required. For this example, use the 2010 NBC.

HRV INFORMATION:

The HRV has an apparent sensible recovery effectiveness of 80% for heating season operation at -13 °F.

Adjusted total recovery efficiency of the HRV for cooling season operation is not reported. Assume zero for the adjusted total recovery efficiency.

FOUNDATION INFORMATION:

Basement Foundation
Concrete Walls and Floor
Interior wall insulation without slab insulation:
Interior surface of wall insulated over full height
(Use configuration BCIN_1)

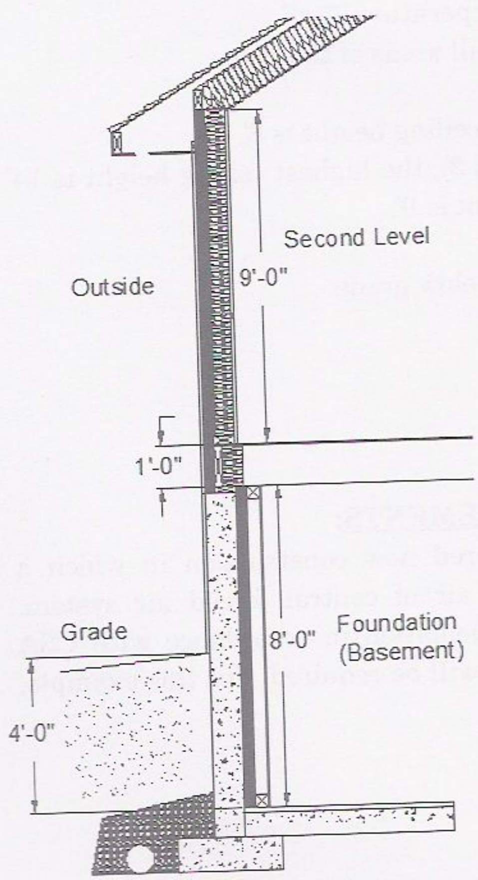
ENVELOPE CONSTRUCTION:

Main Floor (Level 2) Ceiling (Cathedral Ceiling)

- Outside air film (vented roof air space)
- 2 x 10" wood ceiling joists @ 16" o.c. filled with R28 glass fibre batt cavity insulation
- 1/2" gypsum board (interior finish)
- Inside air film

Main Floor (Level 2) Wall

- Outside air film
- 3/4" cement stucco cladding
- Plastic housewrap (seal, plastic film)
- 1" extruded polystyrene (Type 4)
- 3/8" plywood sheathing (generic softwood)
- 2" x 4" wood studs @ 16" o.c. filled with R-14 glass fibre batt cavity insulation
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film



Foundation (Level 1) Header

- Outside air film
- 3/4" cement stucco cladding
- Plastic housewrap (seal, plastic film)
- 1" extruded polystyrene (Type 4)
- 3/8" plywood sheathing (generic softwood)
- 1-1/2" lumber (structural framing, spruce-pine-fir)
- Framed with wood floor joists @ 16" o.c. with R-14 glass fibre batt cavity insulation along joist parallel to exterior wall
- Inside air film

Foundation (Level 1) Wall

- Outside air film
- 3/4" cement stucco cladding
- 8" concrete (150 lb/ft³)
- 3" extruded polystyrene (XPS) (Type 4)
- 1" x 4" strapping applied flat to the wall
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film

Foundation (Level 1) Floor

- 4" concrete slab (150 lb/ft³)
- Linoleum tile
- Inside air film, floor (heat flow down)

<u>WINDOWS</u>:

Double glazed, operable aluminium, metal spacers, clear coatings, ½" glazing spacing, argon filled.
No interior shading.

Foundation level windows have height of 2'.
Second level windows have height of 4'.

<u>DOORS</u>:

Insulated fibreglass polyurethane core with storm.

Unless otherwise stated, door heights are 7'.

<u>AIR LEAKAGE:</u>

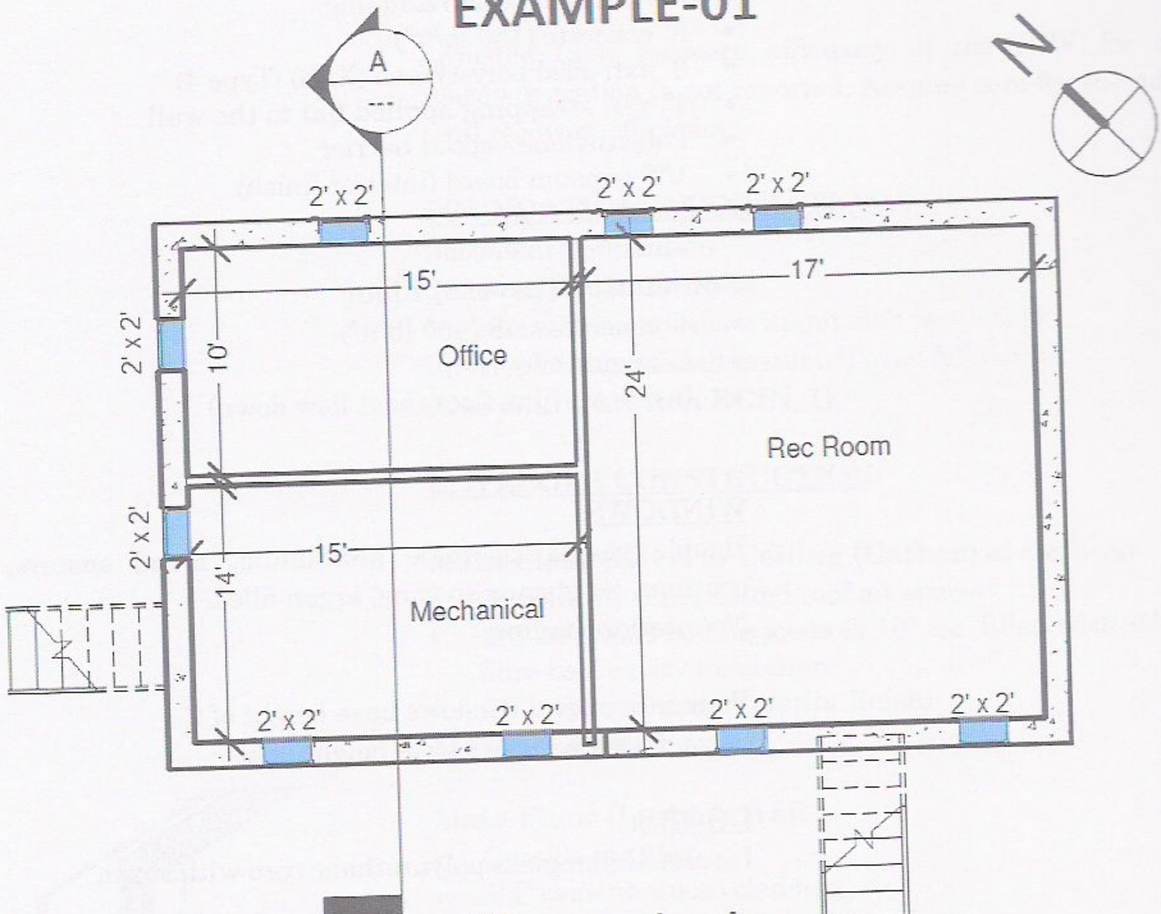
Air tightness level: Energy Tight
Building Site (Shielding class): Open sea
Sheltering level – Walls: No local shielding.
Sheltering level – Flues: No local shielding.
Heating air leakage rate (LR_{airh}) = 0.208/h
Cooling air leakage rate (LR_{airc})= 0.099/h

<u>PEOPLE AND APPLIANCES:</u>

Allow for <u>all</u> people in the Living Room
Appliance and plug loads are distributed to the Living Room and Kitchen

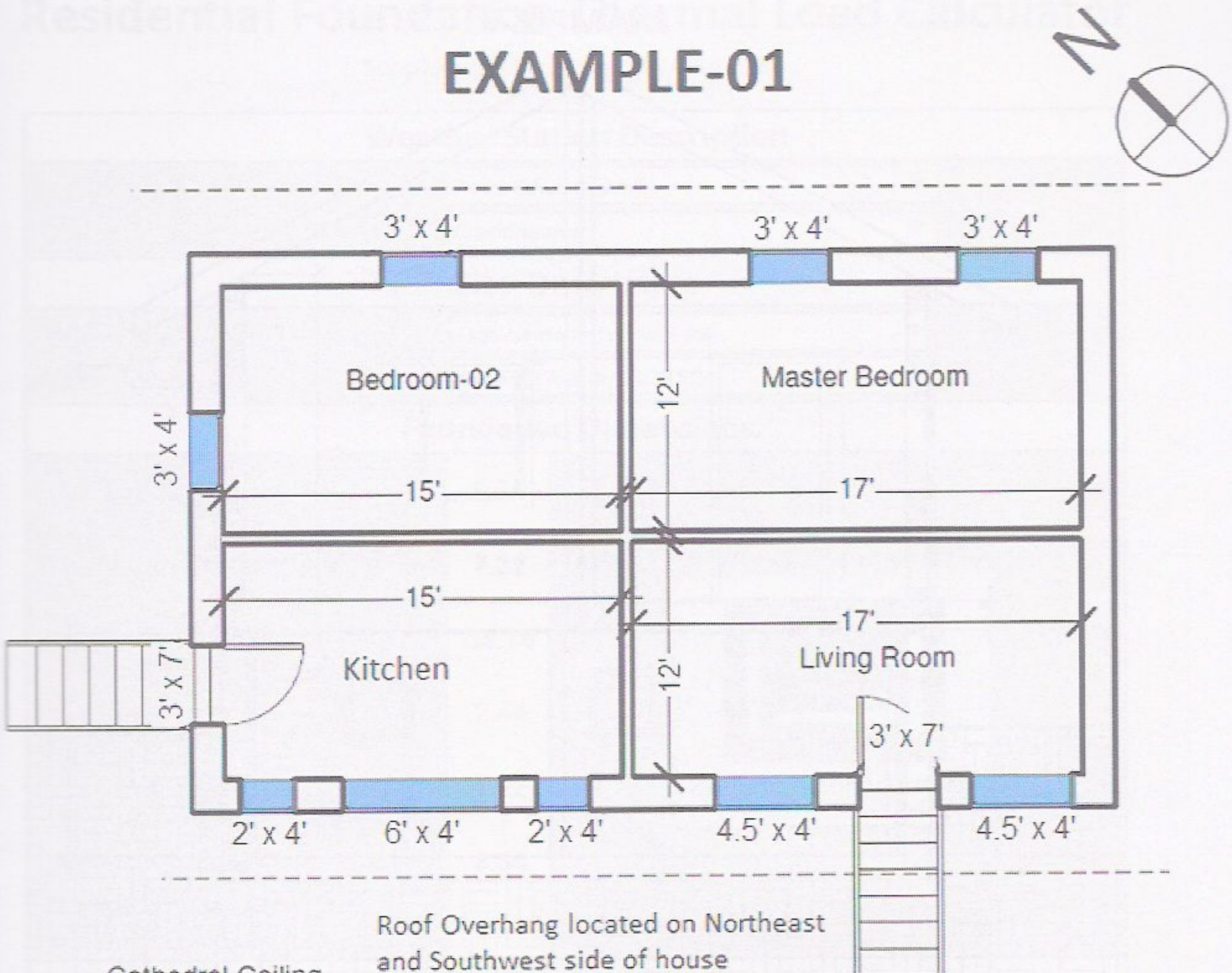
***Note A: ignore duct/pipe heat loss & gain in this calculation**

EXAMPLE-01



Foundation

EXAMPLE-01



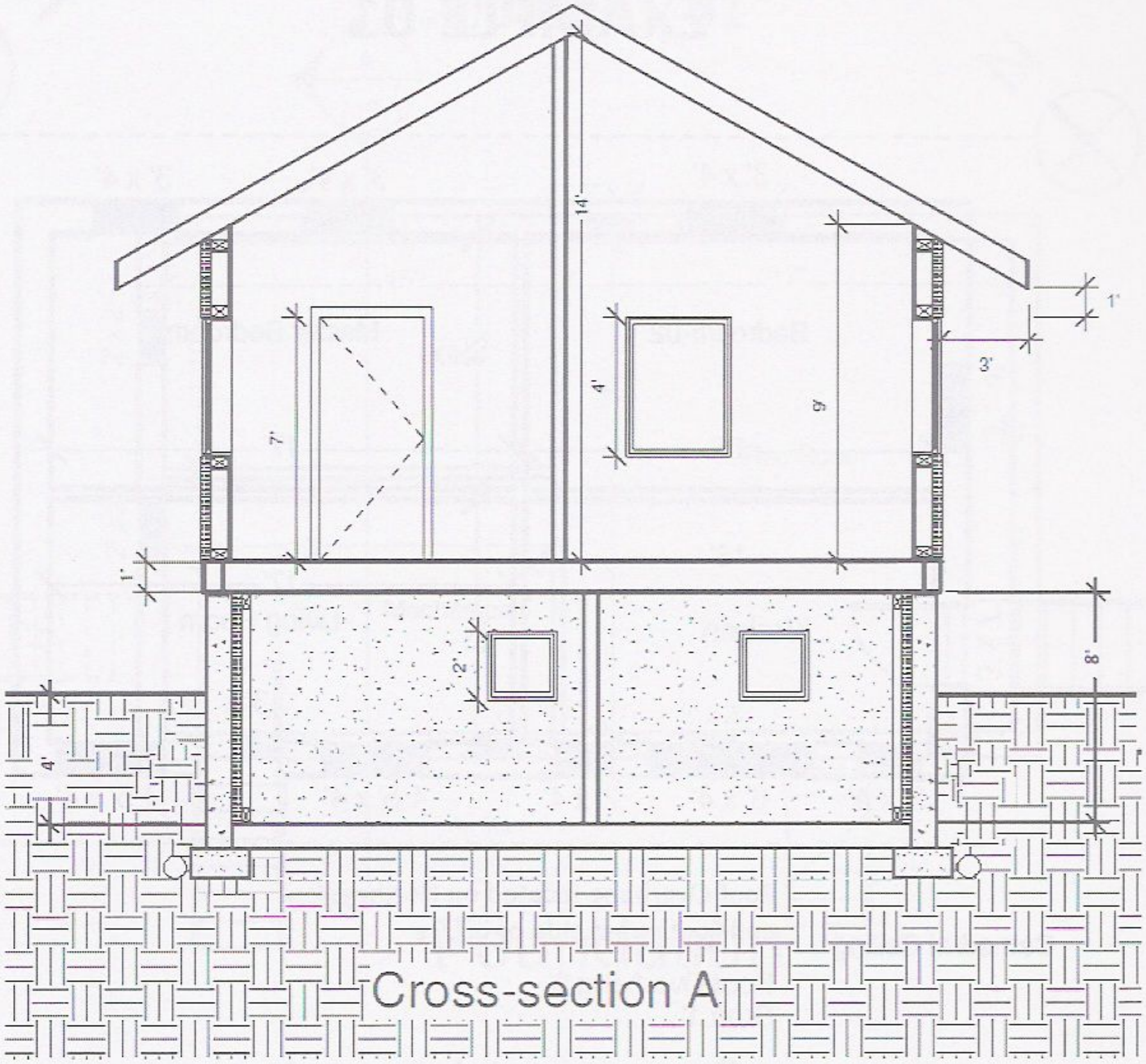
Cathedral Ceiling

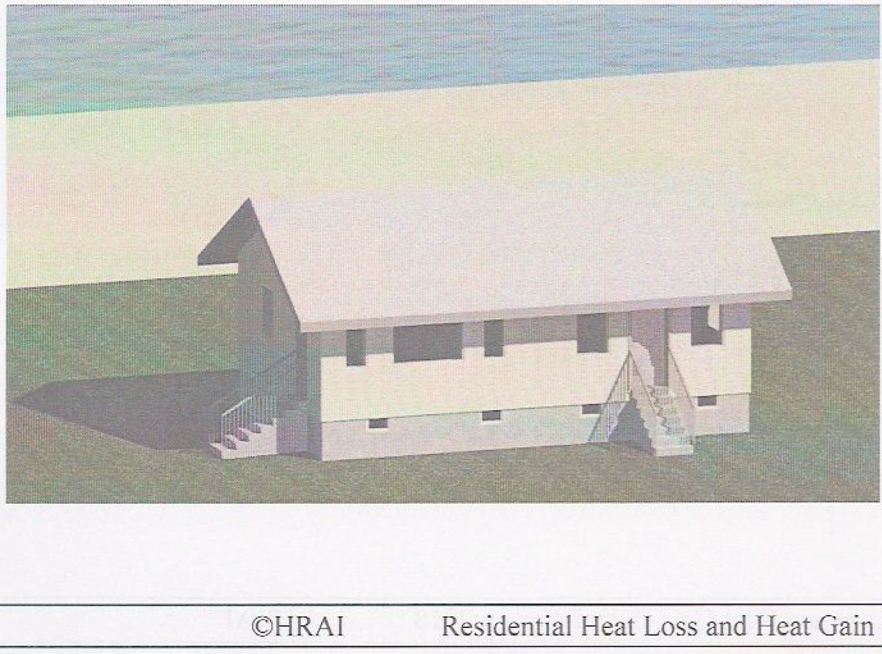
Roof Overhang located on Northeast and Southwest side of house

Roof Overhang 3'
Drop 1'

Second Level

EXAMPLE-01

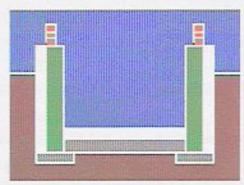




Residential Foundation Thermal Load Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description	
Province:	Prince Edward Island
Region:	Charlottetown
Site Description	
Soil Conductivity:	High conductivity: moist soil
Water Table:	Normal (7-10 m, 23-33 Ft)
Foundation Dimensions	
Floor Length (m):	9.75
Floor Width (m):	7.32
Exposed Perimeter (m):	34.14
Wall Height (m):	2.44
Depth Below Grade (m):	1.22
Window Area (m^2):	3.34
Door Area (m^2):	0
Radiant Slab	
Heated Fraction of the Slab:	0
Fluid Temperature (°C):	33
Design Months	
Heating Month	1
Foundation Loads	
Heating Load (Watts):	**1484**

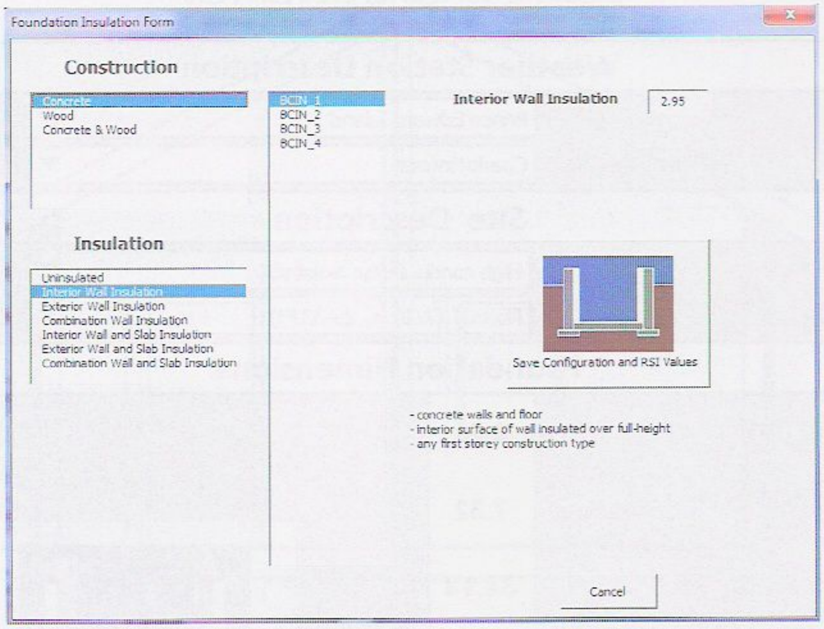


Insulation Configuration

Conductive Heat Loss for Basement Foundation
(includes Heat Loss from above grade basement walls)
= 1484 W
= 1484 × 3.412 = 5063 Btu/h

Basement conductive heat loss is to be apportioned to each room at basement level based on exposed perimeter ratio.

Insulation Configuration for Foundation Thermal Load Calculator



Structure	Foundation (Level 1) Wall – Below Grade - Excluding Concrete Wall & Air Film		
Layer		R-Value	Reference
8” concrete (150 lb/ft³) (= 8 × 0.058)		Excl.	Excl.
Interior Side of Concrete Wall	3” extruded polystyrene (XPS) (Type 4)	15.15	App. B, B-3
	1” × 4” strapping applied without cavity insulation	1.14	App. A, Table 1
	Polyethylene vapour barrier	-	-
	1/2” gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)		Excl.	Excl.
R-VALUE ON INTERIOR SIDE OF CONCRETE WALL		**16.73**	
RSI-VALUE = R-Value × 0.1761		**2.95**	

Structure	Foundation (Level 1) Slab on Grade Floor – Excluding Concrete Slab & Air Film	
Layer	R-Value	Reference
4” concrete slab (150 lb/ft³)	Excl.	Excl.
Linoleum tile	0.05	App. B, B-5
Interior air film - floors	Excl.	Excl.
R-VALUE ABOVE CONCRETE SLAB	**0.05**	**Uninsulated**
RSI-VALUE = R-Value × 0.1761	**0.01**	

Envelope Air Leakage Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description				
Province:	Prince Edward Island			
Region:	Charlottetown			
Weather Station Location:	Open flat terrain, grass			
Anemometer height (m):	10			
Local Shielding				
Building Site:	Open sea, fetch > 5 km			
Walls:	No local shielding			
Flue:	No local shielding			
Highest Ceiling Height (m):	5.791			
Building Configuration				
Type:	Detached			
Number of Stories:	One			
Foundation:	Full			
House Volume (m^3):	445.82			
Air Leakage/Ventilation				
Air Tightness Type:	Energy Tight (ACH=1.5)			
Custom BDT Data:	ELA @ 10 Pa.	161.48 cm^2		
	1.5	ACH @ 50 Pa		
Mechanical Ventilation (L/s):	Total Supply: 28	Total Exhaust: 28		
Flue Size				
Flue #:	#1	#2	#3	#4
Diameter (mm):	0	0	0	0
Envelope Air Leakage Rate				
Heating Air Leakage Rate (ACH/H):	**0.208**			
Cooling Air Leakage Rate (ACH/H):	**0.099**			

CALCULATIONS:

Heat Loss ΔT = IDT – ODT = 72 – (-4) = 76 °F

(Appendix D, page D-18)

Heat Gain ΔT = ODT – IDT = 79 – 75 = 4 °F

(Appendix D, page D-18)

R-value Calculation:

Structure	Main Floor (Level 2) Ceiling (Cathedral Ceiling)	
Layer	R-Value	Reference
Outside air film (vented roof air space)	0.17	App. B, B-2
2" × 10" wood ceiling joists @ 16" o.c. filled with R28 glass fibre batt cavity insulation	21.19	App. A, Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (ceiling)	0.62	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**22.42**	

Structure	Main Floor (Level 2) Wall	
Layer	R-Value	Reference
Outside air film	0.17	App. B, B-2
3/4" cement stucco cladding (= 0.75 × 0.13)	0.10	App. B, B-2
Plastic housewrap (seal plastic film)	-	-
1" extruded polystyrene (XPS) (Type 4)	5.05	App. B, B-3
3/8" plywood sheathing (generic softwood) (= 0.375 × 1.26)	0.47	App. B, B-4
2" × 4" wood studs @ 16" o.c. filled with R14 batt insulation	9.22	App. A, Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**16.13**	

Structure	Foundation (Level 1) Header	
Layer	R-Value	Reference
Outside air film	0.17	App. B, B-2
3/4" cement stucco cladding (= 0.75 × 0.13)	0.10	App. B, B-2
Plastic housewrap (seal plastic film)	-	-
1" extruded polystyrene (XPS) (Type 4)	5.05	App. B, B-3
3/8" plywood sheathing (generic softwood) (= 0.375 × 1.26)	0.47	App. B, B-4
1-1/2" lumber (structural framing, spruce-pine-fir) (= 1.5 × 1.23)	1.85	App. B, B-4
Framed with wood floor joists @ 16" o.c. with R14 batt insulation	14.03	App. A, Table 1
Inside air film (walls)	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**22.35**	

Structure	Foundation (Level 1) Wall – Above Grade	
Layer	R-Value	Reference
Outside air film	0.17	App. B, B-2
3/4" cement stucco cladding (= 0.75 × 0.13)	0.10	App. B, B-2
8" concrete (150 lb/ft³) (= 8 × 0.058)	0.46	App. B, B-4
3" extruded polystyrene (XPS) (Type 4)	15.15	App. B, B-3
1" × 4" strapping applied without cavity insulation	1.14	App. A, Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film (walls)	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	**18.14**	

Windows R-Value = 1.14 (Appendix A, Table 3)

Doors R-Value = 6.81 (Appendix A, Table 6)

Windows SHGC = 0.63 (Appendix A, Table 3)

SOLAR (latitude adjusted solar incident)

North & Shaded = 29 Btu/h/ft² (Appendix A, Table 13)

Northeast /Northwest = 62 Btu/h/ft²
(Appendix A, Table 13)

Southeast / Southwest = 98 Btu/h/ft²

(Appendix A, Table 13)

Internal Shading Factor (ISF) = 1 (Appendix A, Table 14)

Transparent Assembly Heat Gain Multiplier (THGM)

$$= \frac{HG\Delta T}{R} + (SHGC \times SOLAR \times ISF)$$

THGM (North & Shaded)

$= 4 \div 1.14 + 0.63 \times 1 \times 29 = 21.78$

THGM (Northeast / Northwest)

$= 4 \div 1.14 + 0.63 \times 1 \times 62 = 42.57$

THGM (Southeast / Southwest)

$= 4 \div 1.14 + 0.63 \times 1 \times 98 = 65.25$

Heating Air Leakage Rate (LR_{airh}) = 0.208
(from Envelope Leakage Calculator)

Cooling Air Leakage Rate (LR_{airc}) = 0.099
(from Envelope Leakage Calculator)

HL_{leak}
$= B \times LR_{airh} \times Vb \times HL\Delta T$
$= 0.018 \times 0.208 \times 15744 \times 76 = 4480$ Btu/h

HG_{leak}
$= B \times LR_{airc} \times Vb \times HG\Delta T$

$= 0.018 \times 0.099 \times 15744 \times 4 = 112$ Btu/h

Air Leakage Heat Loss Multiplier

$= \text{Level Factor} \times HL_{leak} \div \text{Level Conductive Heat Loss}$

Level 1 Air Leakage Heat Loss Multiplier

$= 0.6 \times 4480 \div 7843 = 0.3427$

Level 2 Air Leakage Heat Loss Multiplier

$= 0.4 \times 4480 \div 16086 = 0.1114$

Air Leakage Heat Gain Multiplier

(Applicable to all levels)

$= HGleak \div \text{Building Conductive Heat Gain}$

$= 112 \div 8523 = 0.0131$

$$\mathbf{HL_{bvent}} = C \times PVC \times HL\Delta T \times (1 - E)$$
$$= 1.08 \times 59 \times 76 \times (1 - 0.80) = 969 \text{ Btu/h}$$

$$\mathbf{HG_{bvent}} = C \times PVC \times HG\Delta T \times (1 - ATRE)$$
$$= 1.08 \times 59 \times 4 \times (1 - 0) = 255 \text{ Btu/h}$$

$$\mathbf{HG_{bvent}} \times 1.3 = 255 \times 1.3 = 332 \text{ Btu/h}$$

These are the basic calculations to be transferred to the worksheet. From the R-values and various factors, the required multipliers can be calculated, and from the dimensions on the house plans, all required areas can be calculated. After entering the multipliers and area on the worksheet, the heat loss and heat gain can be calculated.

HRAI Residential Heat Loss and Heat Gain Calculations				Page 1 of 8	
	BUILDING LOCATION				
	Model	Example-01		Site	Millwood Heights
	Address	456 Mills Road		Lot	Lot 5
	City and Province	Charlottetown, PEI		Postal Code	C2E 5F4

SUBMITTED FOR		DESIGNED/SUBMITTED BY:	
Name	Carol Collins	Name	Mark Jacob
	CC Builders	Company	MJ Consulting Inc.
Address	123 Ilusion Road	Address	654 Chestnut Drive
City and Province	Charlottetown, PEI Postal Code A1A 1A1	City and Province	Charlottetown, PEI Postal Code A1B 1C1
Telephone	123-452-2143	Telephone	123-562-5633
E-mail	Carol@CCBuilders.ca	E-mail	Mark@MJConsulting.ca

FOR DESIGNER'S USE:			
Signature:	Date Prepared (MM/DD/YY)	HRAI #	Other Certification # (e.g. BCIN)
	01/01/2015	xxxxx	BCIN: xxxxx

SECTION A	BUILDING CONSTRUCTION DETAILS		
Plan & Drawing No:	Any-Design Drawings Dated 08/09/2014		
Attachment:	Detached	Front facing:	Southwest Assumed ☐ Yes ☑ No
No. of Stories	1 + Basement	Air tightness:	Energy Tight Assumed ☑ Yes ☐ No
Weather location	Charlottetown, PEI Ventilated ☑ Yes ☐ No	Local Shielding:	No local shielding
HRV Model	Model-XXXXX6 ☐ N/A	Internal Shading:	No interior shading Occupants: 3
		Units:	☑ Imperial ☐ Metric

Building Envelope Assemblies

Above Grade Walls		Windows & Skylights	
Structure: MFW	3/4" cement stucco cladding, 1" Type 4 XPS, 2 x 4 wood studs @ 16" filled with R14 glass fibre	Structure: WN	Double glazed, operable aluminum, metal spacers, clear coatings, 1/2" glazing spacing,
Structure: FW	3/4" cement stucco cladding, 8" concrete, 3" Type 4 XPS, 1 x 4 strapping	Structure:	
Structure:		Structure:	
Structure:		Structure:	

Below Grade Walls		Headers	
Structure: BGW	8" concrete, 3" Type 4 XPS,1 x 4 strapping	Structure: H	3/4" cement stucco cladding, 1" Type XPS, 1-1/2" lumber, framed @ 16" filled with R14 batt
Structure:		Structure:	

Ceilings		Floors on Soil	
Structure: EXC	2 x 10 wood ceiling joists @ 16" o.c. filled with R28 glass fibre batt insulation	Structure: FF	Linoleum tile, 4" concrete slab
Structure:		Structure:	

Doors		Exposed Floors	
Structure: D	Insulated fibreglass polyurethane core with storm	Structure:	
Structure:		Structure:	

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HRAI Residential Heat Loss and Heat Gain Calculations Page 2 of 8

SECTION B — DESIGN CONDITIONS

HEAT LOSS			HEAT GAIN		
Outdoor Design Temperature Heating (ODT)	-4	°F / ~~°C~~	Outdoor Design Temperature Cooling (ODT)	79	°F / ~~°C~~
Indoor Design Temperature (IDT)	72	°F / ~~°C~~	Indoor Design Temperature (IDT)	75	°F / ~~°C~~
Mean Soil Temperature	46	°F / ~~°C~~	North Latitude	46	°
			Summer Mean Daily Temperature Range	16	°F / ~~°C~~
Building Volume (Vb)	15744	ft^3 / ~~m^3~~	Building Conditioned Area	1536	ft^2 / ~~m^2~~

HRV Apparent Sensible Effectiveness = 0.80 (insert N/A if no HRV/ERV installed)

Ventilation System:

- ☐ Case #1: Exhaust Only System
- ☐ Case #2: Direct Ducted System
- ☑ Case #3: Central Forced Air System

SECTION C — ROOM HEAT LOSS / HEAT GAIN SUMMARY

Level	Room Name	Total Heat Loss Calculated Section 16 Btuh/~~W~~	Total Heat Gain Calculated Section 17 Btuh/~~W~~	Level	Room Name	Total Heat Loss Calculated Section 16 Btuh/~~W~~	Total Heat Gain Calculated Section 17 Btuh/~~W~~
1	OFF	2347	482				
1	RR	5216	1213				
1	M	2967	948				
2	BR2	3817	1783				
2	MB	4009	1835				
2	LR	4985	5110				
2	K	5068	4335				
				SUB TOTAL		28409 Section 18	15706 Section 21

SECTION D — BUILDING HEAT LOSS SUMMARY

Building Sub Total Heat Loss	(Section 18)	28409	Btuh/~~W~~	
Central Forced Air Ventilation Heat Loss	(Section 19)	969	Btuh/~~W~~	*Only applicable for ventilation case #3
Total Building Heat Loss	(Section 20)	**29378**	Btuh/~~W~~	

SECTION E — BUILDING HEAT GAIN SUMMARY

Building Sub Total Heat Gain	(Section 21)	15706	Btuh/~~W~~	
Central Forced Air Ventilation Heat Gain	(Section 22)	332	Btuh/~~W~~	*Only applicable for ventilation case #3
Total Building Heat Gain	(Section 23)	**16038**	Btuh/~~W~~	

Notes:

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HRAI Residential Heat Loss and Heat Gain Calculations							Page 3 of 8		
		HL ΔT =	76	HG ΔT =		4			
COMPONENTS	STRUCTURE	EFFECTIVE R-VALUE Col 1	HLΔT / R Col 2	SC Col 3	(HGΔT+SC) / R Col 4		P_E 25 H 8 A_F 150 Area	LVL 1 RM OFF HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS	MFW								
	FW						100.00		
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH	1.14	66.67		THGM	21.78			
	S				THGM				
	E/W				THGM				
	NE/NW	1.14	66.67		THGM	42.57	8.00	533	341
	SE/SW	1.14	66.67		THGM	65.25			
	HOR				THGM				
3.EXPOSED DOORS	D	6.81	11.16	0	0.59				
4.NET EXPOSED WALLS	MFW	16.13	4.71	0	0.25			Do not Calculate for Basement	
	FW	18.14	4.19	0	0.22		92.00		20
5.HEADER AREAS	H	22.35	3.40	0	0.18		25.00	85	5
6.EXPOSED CEILINGS	EXC	22.42	3.39	27	1.38				
7.EXPOSED FLOORS									
8.OTHER									
9.FOUNDATION CONDUCTIVE HEAT LOSS	☑ BASEMENT ☐ SLAB ON GRADE							1130	

		LVL 1	LVL 2	LVL 3	LVL 4		HEAT LOSS	HEAT GAIN
10. TOTAL CONDUCTIVE	TOTAL HEAT LOSS	7843	16086				1748	
	TOTAL HEAT GAIN	8523						366
11. AIR LEAKAGE	HEAT LOSS MULTIPLIER	0.3427	0.1114				599	
	HEAT GAIN MULTIPLIER	0.0131						5
12a. VENTILATION: EXHAUST ONLY	HEAT LOSS MULTIPLIER							
	HEAT GAIN MULTIPLIER							
12b. VENTILATION: DIRECT DUCTED SYSTEM	HEAT LOSS MULTIPLIER					Qvr		
	HEAT GAIN MULTIPLIER							
13. INTERNAL HEAT GAIN (PEOPLE, LIGHTS, APPLIANCES, PLUG LOADS)								
14. NET LOADS	ADD SECTIONS (10 + 11 + 12 + 13)						2347	371
15. DUCT / PIPE HEAT LOSS/GAIN THROUGH UNCONDITIONED SPACES						LOSS		
						GAIN		
16. TOTAL HEAT LOSS FOR EACH ROOM	ADD SECTIONS (14 + 15)					LOSS	2347	
17. TOTAL HEAT GAIN FOR EACH ROOM	ADD SECTIONS (14 + 15) x 1.3					GAIN		482

18. SUB TOTAL HEAT LOSS (SUM OF SECTION 16)	28409	20. TOTAL HEAT LOSS ADD SECTIONS (18 + 19)	29378
19. CENTRAL FORCED AIR VENTILATION HEAT LOSS	969		
21. SUB TOTAL HEAT GAIN (SUM OF SECTION 17)	15706	23. TOTAL HEAT GAIN ADD SECTIONS (21 + 22)	16038
22. CENTRAL FORCED AIR VENTILATION HEAT GAIN	332		

HRAI Residential Heat Loss and Heat Gain Calculations									Page 4 of 8	
COMPONENTS	STRUCTURE	P_E 58	LVL	1	P_E 29	LVL	1	P_E 27	LVL	2
		H 8	RM	RR	H 8	RM	M	H 9	RM	BR2
		A_F 408 Area	HEAT LOSS	HEAT GAIN	A_F 210 Area	HEAT LOSS	HEAT GAIN	A_F 180 Area	HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS	MFW							273.00		
	FW	232.00			116.00					
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH									
	S									
	E/W									
	NE/NW	8.00	533	341	4.00	267	170	24.00	1600	1022
	SE/SW	8.00	533	522	8.00	533	522			
	HOR									
3.EXPOSED DOORS	D									
4.NET EXPOSED WALLS	MFW							249.00	1173	62
	FW	216.00	Do not Calculate for Basement	48	104.00	Do not Calculate for Basement	23			
5.HEADER AREAS	H	58.00	197	10	29.00	99	5			
6.EXPOSED CEILINGS	EXC							195.00	661	269
7.EXPOSED FLOORS										
8.OTHER										
9.FOUNDATION HL			2622			1311				
10. TOTAL CONDUCTIVE			3885			2210			3434	
				921			720			1353
11. AIR LEAKAGE			1331			757			383	
				12			9			18
12a. VENTILATION: EXHAUST ONLY										
12b. VENTILATION: DIRECT DUCTED SYSTEM		Qvr			Qvr			Qvr		
13. INTERNAL HEAT GAIN										
14. NET LOADS			5216	933		2967	729		3817	1371
15. DUCT / PIPE HEAT LOSS / GAIN		LOSS			LOSS			LOSS		
		GAIN			GAIN			GAIN		
16. TOTAL HL (ROOM)		LOSS	5216		LOSS	2967		LOSS	3817	
17. TOTAL HG (ROOM)		GAIN		1213	GAIN		948	GAIN		1783

HRAI Residential Heat Loss and Heat Gain Calculations									Page 5 of 8	
COMPONENTS	STRUCTURE	P_E 29	LVL 2		P_E 29	LVL 2		P_E 27	LVL 2	
		H 9	RM MB		H 9	RM LR		H 9	RM K	
		A_F 204 Area	HEAT LOSS	HEAT GAIN	A_F 204 Area	HEAT LOSS	HEAT GAIN	A_F 180 Area	HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS	MFW	291.00			291.00			273.00		
	FW									
2.WINDOWS, GLASS DOORS AND SKYLIGHT	N&SH				20.70	1380	451	23.00	1533	501
	S									
	E/W									
	NE/NW	24.00	1600	1022						
	SE/SW				15.30	1020	998	17.00	1133	1109
	HOR									
3.EXPOSED DOORS	D				21.00	234	12	21.00	234	12
4.NET EXPOSED WALLS	MFW	267.00	1258	67	234.00	1102	59	212.00	999	53
	FW									
5.HEADER AREAS	H									
6.EXPOSED CEILINGS	EXC	221.00	749	305	221.00	749	305	195.00	661	269
7.EXPOSED FLOORS										
8.OTHER										
9.FOUNDATION HL										
10. TOTAL CONDUCTIVE			3607			4485			4560	
				1394			1825			1944
11. AIR LEAKAGE			402			500			508	
				18			24			25
12a. VENTILATION: EXHAUST ONLY										
12b. VENTILATION: DIRECT DUCTED SYSTEM		Qvr			Qvr			Qvr		
13. INTERNAL HEAT GAIN							2082			1365
14. NET LOADS			4009	1412		4985	3931		5068	3334
15. DUCT / PIPE HEAT LOSS / GAIN		LOSS			LOSS			LOSS		
		GAIN			GAIN			GAIN		
16. TOTAL HL (ROOM)		LOSS	4009		LOSS	4985		LOSS	5068	
17. TOTAL HG (ROOM)		GAIN		1835	GAIN		5110	GAIN		4335

HRAI Residential Heat Loss and Heat Gain Calculations
Formula Sheet (For Air Leakage / Ventilation Calculation)

BUILDING AIR LEAKAGE HEAT LOSS

B (M) = 0.33
B (I) = 0.018

$HL_{leak} = B \times LR_{airh} \times Vb \times HL\Delta T$

$= 0.018 \times 0.208 \times 15744 \times 76 = \boxed{4480}$

BUILDING AIR LEAKAGE HEAT GAIN

B (M) = 0.33
B (I) = 0.018

$HG_{leak} = B \times LR_{airc} \times Vb \times HG\Delta T$

$= 0.018 \times 0.099 \times 15744 \times 4 = \boxed{112}$

AIR LEAKAGE HEAT LOSS/GAIN MULTIPLIER TABLE (SECTION 11)

Level	Level Factor (LF)	Building Air Leakage Heat Loss (HL_{leak})	Level Conductive Heat Loss: see Section 10 (HL_{clevel})	Air Leakage Heat Loss Multiplier ($LF \times HL_{leak} \div HL_{clevel}$)
1	0.6	4480	7843	0.3427
2	0.4		16086	0.1114
3				
4				

$$\text{Air Leakage Heat Gain Multiplier} = \frac{HG_{leak}}{\text{Building Conductive Heat Gain}} = \frac{112}{8523} = \boxed{0.0131}$$

VENTILATION HEAT LOSS

C (M) = 1.2
C (I) = 1.08

$HL_{bvent} = C \times PVC \times HL\Delta T \times (1 - E)$

$= 1.08 \times 59 \times 76 \times 0.20 = \boxed{969}$

VENTILATION HEAT GAIN

C (M) = 1.2
C (I) = 1.08

$HG_{bvent} = C \times PVC \times HG\Delta T \times (1 - ATRE)$

$= 1.08 \times 59 \times 4 \times 1.00 = \boxed{255}$

Case #1: Exhaust Only System (Section 12a)

Multiplier = Level Factor x HL_{bvent} ÷ Level Cond. Heat Loss

Level	LF	HL_{bvent}	LVL Cond. HL	Multiplier
1				
2				
3				
4				

HL_{rvent} = Multiplier x Room Conductive Heat Loss

Case #1: Exhaust Only System (Section 12a)

$$\text{Multiplier} = \frac{HG_{bvent}}{\text{Building Conductive Heat Gain}}$$

Multiplier = ______ = $\boxed{}$

HG_{rvent} = Multiplier x Room Conductive Heat Gain

Case #2: Direct Ducted System (Section 12b)

C (M) = 1.2
C (I) = 1.08

Multiplier = $C \times HL\Delta T \times (1 - E)$

Multiplier = ____ x ____ x ____ = $\boxed{}$

Q_{vr} = Room Ventilation Rate

HL_{rvent}= Multiplier x Q_{vr}

Case #2: Direct Ducted System (Section 12b)

C (M) = 1.2
C (I) = 1.08

Multiplier = $C \times HG\Delta T \times (1 - ATRE)$

Multiplier = ____ x ____ x ____ = $\boxed{}$

Q_{vr} = Room Ventilation Rate

HG_{rvent} = Multiplier x Q_{vr}

Case #3: Central Forced Air System (Section 19)

Enter HL_{bvent} in Section 19

Case #3: Central Forced Air System (Section 22)

HG_{bvent} x 1.3 = $\boxed{255}$ x 1.3 = $\boxed{332}$
(enter in Section 22)

HRAI WINDOW SHADING WORKSHEET

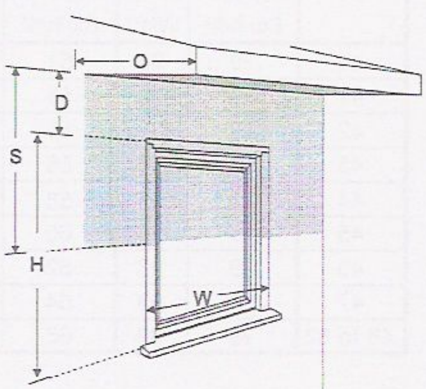
Page 7 of 8

Latitude = 46 °

Level	2	2					
Room Name	LR	K					
Direction Window Faces	SW	SW					
W (ft / ~~m~~) Width of Window	9	10					
H (ft / ~~m~~) Height of Window	4	4					
A (ft^2 / ~~m^2~~) Total Window Area	36	40					
O (ft / ~~m~~) Width of Overhang	3	3					
F (see Table below) F-Shade Factor	1.1	1.1					
S (ft / ~~m~~) S = F x O Shade Line	3.3	3.3					
D (ft / ~~m~~) Drop	1	1					
SA (ft^2 / ~~m^2~~) SA = (S-D) x W Shaded Area	20.7	23					
UA (ft^2 / ~~m^2~~) UA = A - SA Unshaded Area	15.3	17					

NOTES:

1. Shaded area SA will be marked on the HRAI Worksheets as "north"
2. Unshaded area (UA) will be marked on the HRAI Worksheets as the direction the window actually faces
3. Shading calculations are not required for north, northeast and northwest facing windows.
4. If the shaded area (SA) is greater than the window area (A), then: SA = A Shaded area (SA) is never more than window area (A)
5. If shaded area (SA) is negative use a value of zero.



F Shade Factor							
Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

HRAI WINDOW SHADING WORKSHEET

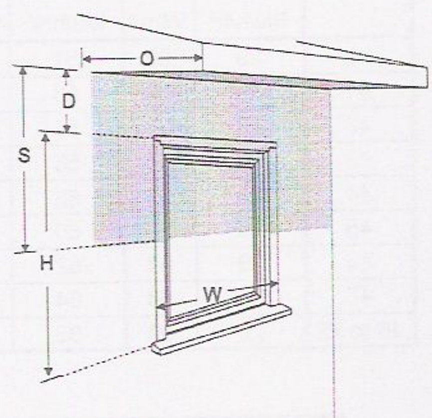
Page 7 of 8

Latitude = 46 °

Level	2	2					
Room Name	LR	K					
Direction Window Faces	SW	SW					
W (ft / ~~m~~) Width of Window	9	10					
H (ft / ~~m~~) Height of Window	4	4					
A (ft² / ~~m²~~) Total Window Area	36	40					
O (ft / ~~m~~) Width of Overhang	3	3					
F (see Table below) F-Shade Factor	1.1	1.1					
S (ft / ~~m~~) S = F x O Shade Line	3.3	3.3					
D (ft / ~~m~~) Drop	1	1					
SA (ft² / ~~m²~~) SA = (S-D) x W Shaded Area	20.7	23					
UA (ft² / ~~m²~~) UA = A - SA Unshaded Area	15.3	17					

NOTES:

1. Shaded area SA will be marked on the HRAI Worksheets as "north"
2. Unshaded area (UA) will be marked on the HRAI Worksheets as the direction the window actually faces
3. Shading calculations are not required for north, northeast and northwest facing windows.
4. If the shaded area (SA) is greater than the window area (A), then: SA = A Shaded area (SA) is never more than window area (A)
5. If shaded area (SA) is negative use a value of zero.



F Shade Factor							
Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

TRANSPARENT ASSEMBLY HEAT GAIN MULTIPLIER (THGM) WORKSHEET

Transparent Assembly Heat Gain Multiplier (THGM)

$$THGM = \frac{HG\Delta T}{R} + (SHGC \times SOLAR \times ISF)$$

THGM Calculation Table

		Facing Direction					
		North & Shaded	South	East / West	Northeast / Northwest	Southeast / Southwest	Horizontal
North Latitude		46 °					
HG∆T		4 °F / ~~°C~~					
Effective R-value		1.14			1.14	1.14	
#1	$\frac{HG\Delta T}{R}$	3.51			3.51	3.51	
#2	SHGC	0.63			0.63	0.63	
#3	SOLAR	29			62	98	
#4	ISF	1			1	1	
#5	(#2) × (#3) × (#4)	18.27			39.06	61.74	
#6	THGM=(#1) + (#5)	21.78			42.57	65.25	

SOLAR = Estimated Solar Radiation

Latitude	North & Shaded		South		East / West		Northeast / Northwest		Southeast / Southwest		Horizontal	
	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²
40	29	93	51	160	90	285	62	194	80	252	169	534
41	29	93	53	166	90	285	62	194	83	261	169	534
42	29	93	55	172	90	285	62	194	86	271	169	534
43	29	93	56	178	90	285	62	194	89	280	169	534
44	29	93	58	184	90	285	62	194	92	290	169	534
45	29	93	60	190	90	285	62	194	95	299	169	534
46	29	93	62	196	90	285	62	194	98	309	169	534
47	29	93	64	202	90	285	62	194	101	318	169	534
48 to 82	29	93	66	208	90	285	62	194	104	328	169	534

ISF = Internal Shading Factors

Type of interior shading	Type of glazing systems			
	Single	Double	Triple	Heat Mirror
No interior shades	1	1	1	1
Interior blinds, curtains, and etc.	0.50	0.55	0.57	0.60
Interior reflective metallic blinds or screens	0.35	0.37	0.40	0.44

4 Worksheet Examples

Example-02

LOCATION:

This detached house was built in Stettler, Alberta in 2011. The foundation is a slab-on-grade. There are two storeys above grade (Level 1 and Level 2). Arrange rooms in the following order on the worksheet:

Main Floor (Level 1):
K (Kitchen), Den, and FR (Family Room)

Second Floor (Level 2):
MB (Master Bedroom), RA (Reading Area), OFF (Office), and BR2 (Bedroom-2)

DESIGN CONDITIONS:

Winter indoor design temperature 72 °F.
Summer indoor design temperature 75 °F.
Indoor conditions apply to all areas of the house
All ceiling heights 8'.
12" header.

SITE CONDITION:

Soil conductivity is very wet.
Water table is normal.

VENTILATION REQUIREMENTS:

The house has a direct ducted HRV. Ventilation is supplied to rooms as per 2010 NBC. The ventilation rates for the rooms are listed as follows:

Total PVC = 59 cfm

Master Bedroom = 20 cfm
Bedroom 2 = 20cfm
Family Room = 19 cfm

HRV INFORMATION:

The HRV has an apparent sensible recovery effectiveness of 76% for heating season operation at -13 °F.

Adjusted total recovery efficiency of the HRV for cooling season operation is not reported. Assume zero for the adjusted total recovery efficiency.

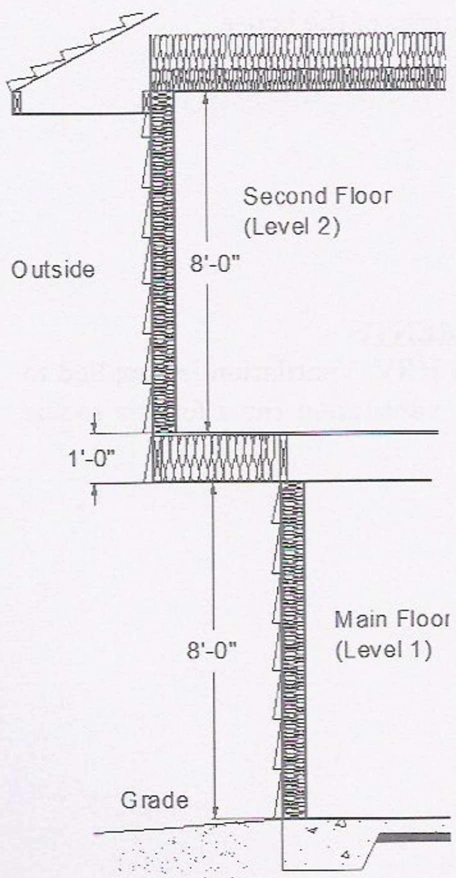
FOUNDATION INFORMATION:

Slab-on-grade foundation
Concrete floor
Bottom of slab is fully insulated except under footing/foundation (full below slab insulation without skirt)
Main floor is non-brick veneer
(Use configuration SCB_25)

ENVELOPE CONSTRUCTION:

Second Floor (Level 2) Ceiling (Vented Attic)

- Outside air film (vented roof air space)
- 10" loose fill glass fibre insulation on top of ceiling joists
- 2 x 6" wood ceiling joists @ 16" o.c. filled with 5-1/2" loose fill glass fibre cavity insulation
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film



Second Floor (Level 2) Wall

- Outside air film
- Vinyl siding (hollow backed)
- Plastic housewrap (seal, plastic film)
- 3/8" plywood sheathing
- 2" x 6" wood studs @ 16" o.c. filled with R-20 glass fibre batt cavity insulation
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film

Second Floor (Level 2) Exposed Floor

- Outside air film
- Vinyl (hollow backed)
- 1/2" plywood sheathing (generic softwood)
- 2" x 12" floor joists @ 16" o.c. filled with R-40 glass fibre batt cavity insulation
- Polyethylene vapour barrier
- 3/4" plywood (generic softwood)
- Inside air film

Main Floor (Level 1) Header

- Outside air film
- Vinyl Siding (hollow backed)
- Plastic housewrap (seal, plastic film)
- 3/8" plywood sheathing (generic softwood)
- 1-1/2" lumber (structural framing, spruce-pine-fir)
- Framed with wood floor joists @ 16" o.c. with R-20 glass fibre batt cavity insulation along joist parallel to exterior wall
- Inside air film

Main Floor (Level 1) Wall

- Outside air film
- Vinyl Siding (hollow backed)
- Plastic housewrap (seal, plastic film)
- 3/8" plywood sheathing (generic softwood)
- 2" x 6" wood studs @ 16" o.c. filled with R-20 glass fibre batt cavity insulation
- Polyethylene vapour barrier
- 1/2" gypsum board (interior finish)
- Inside air film

Main Floor (Level 1) Slab (Slab-on-Grade)

- 2.5" extruded polystyrene (XPS) (Type 4) below the concrete floor
- 4" concrete slab (150 lb/ft^3)
- Carpet and rubber underpad
- Inside air film, floor (heat flow down)

<u>WINDOWS:</u>

Double glazed, operable vinyl, insulating spacers, clear coatings, 1/2" glazing spacing, argon filled.
No interior shading

Window heights are indicated on building plans.

<u>DOORS:</u>

Solid wood 1 ¾" thick without storm.
Unless otherwise stated, door heights are 7'.

AIR LEAKAGE:

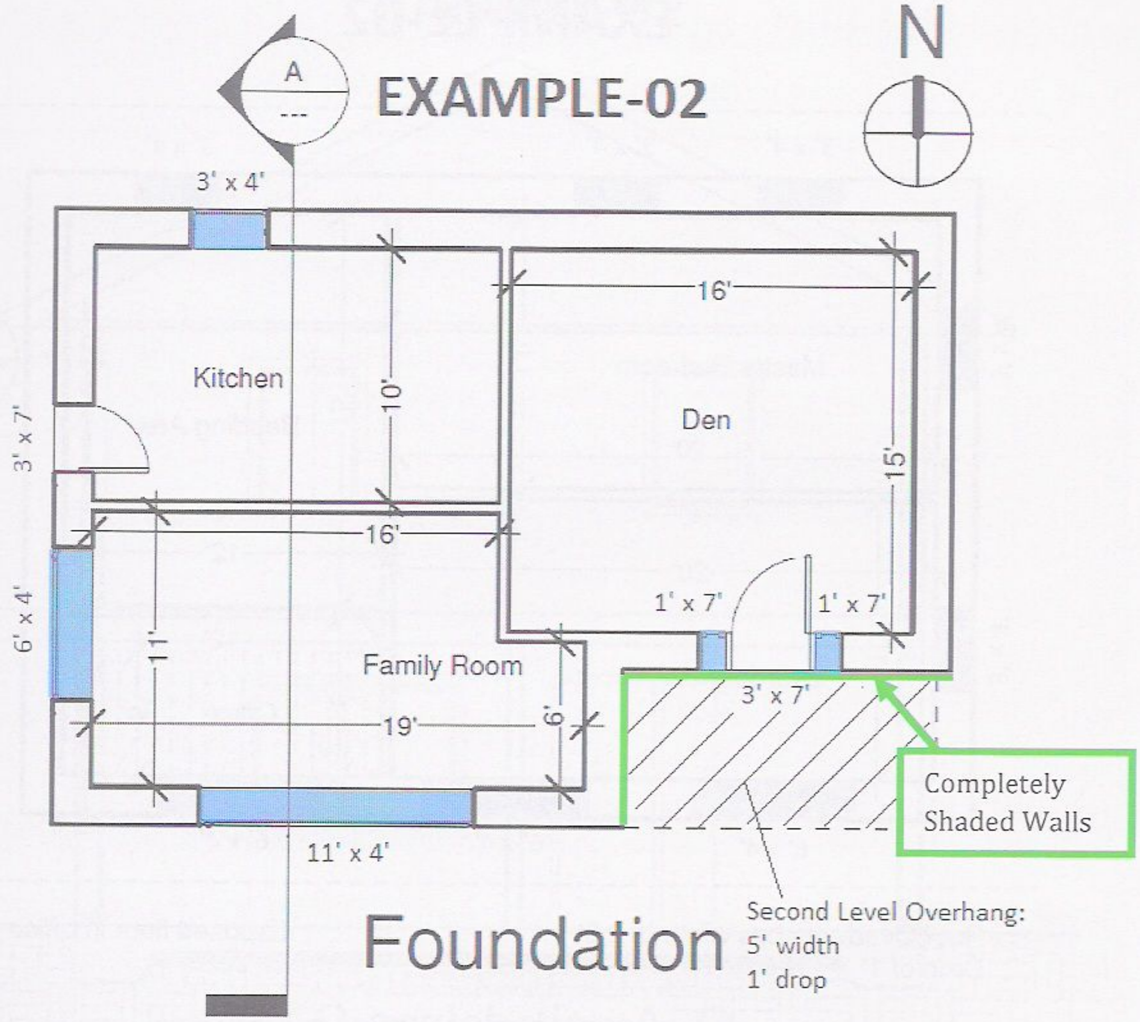
Air tightness level: Energy Tight
Building Site (Shielding Class): Low crops
Shielding Level – Walls: Heavy shielding
Shielding Level – Flue: Heavy shielding

Heating air leakage (LR_{airh}) = 0.152/h
Cooling air leakage (LR_{airc}) = 0.048/h

PEOPLE AND APPLIANCES:

Allow for all people in the Family Room
Appliance and plug loads are distributed to Kitchen and Family Room

***Note A: ignore duct/pipe heat loss & gain in this calculation**


A

EXAMPLE-02
N
3' x 4'
Kitchen
10'
16'
Den
15'
3' x 7'
16'
6' x 4'
11'
Family Room
1' x 7'
1' x 7'
3' x 7'
19'
6'
Completely
Shaded Walls
11' x 4'
Foundation
Second Level Overhang:
5' width
1' drop

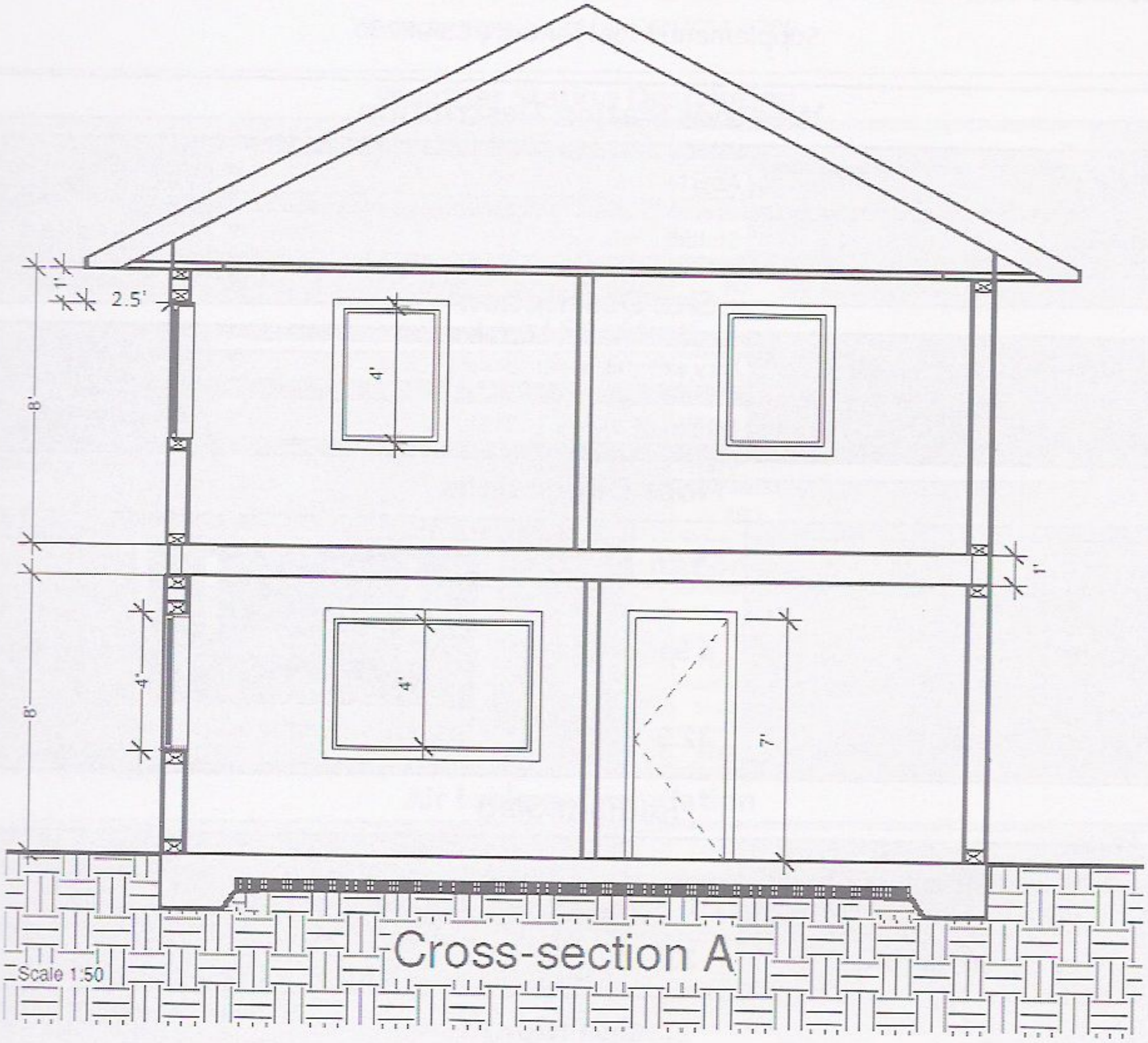
EXAMPLE-02

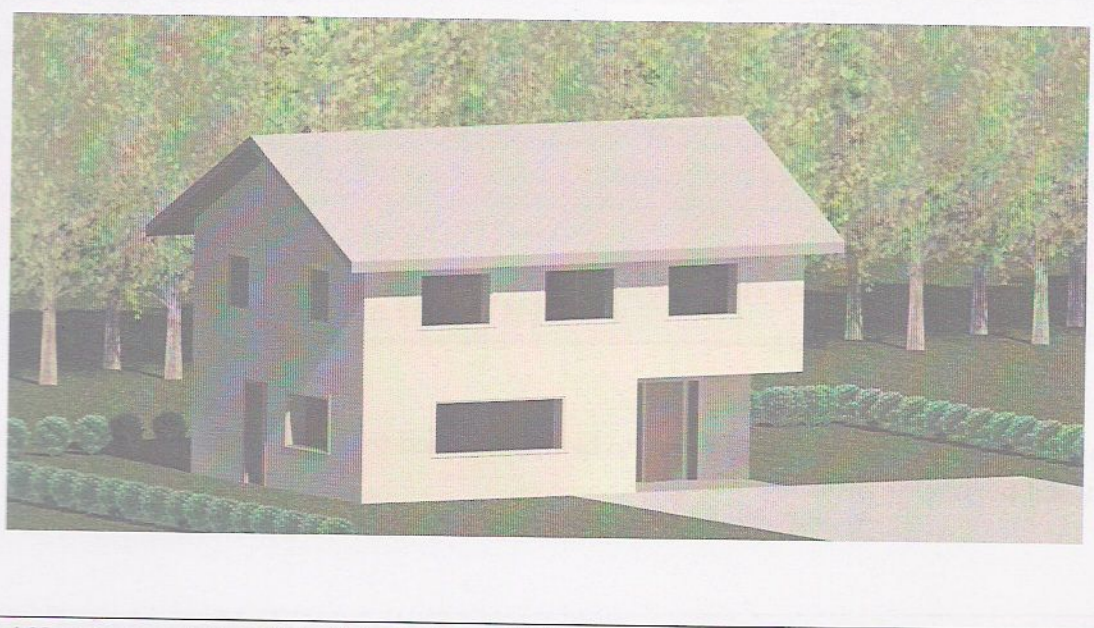
Roof Overhang has width of 2.5'
Drop of 1'

Exposed floor in office
12' X 5'

Second Level

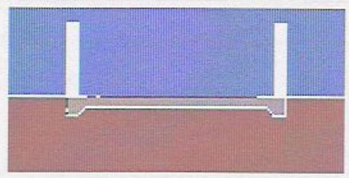
EXAMPLE-02





Residential Slab on Grade Thermal Load Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description		
Province:	Alberta	
Region:	Stettler	
Site Description		
Soil Conductivity:	Very wet soils or perma-frost	
Water Table:	Normal (7-10 m, 23-33 Ft)	
Floor Dimensions		
Length (m):	11.25	 Insulation Configuration
Width (m):	4.91	
Exposed Perimeter (m):	32.3	
Radiant Slab		
Heated Fraction of the Slab:	0	
Fluid Temperature (°C):	33	
Design Month		
Heating Month	1	
Results		
Heating Load (Watts):	**670**	

Slab-on-Grade Conductive Heat Loss

= 670 W x 3.412 = 2286 Btuh

Slab-on-Grade Conductive Heat Loss is to be apportioned to each room at foundation level based on exposed perimeter ratio.

Envelope Air Leakage Calculator

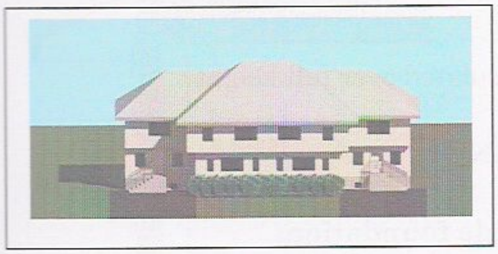
Supplemental tool for CAN/CSA-F280

Weather Station Description			
Province:	Alberta		
Region:	Stettler		
Weather Station Location:	Open flat terrain, grass		
Anemometer height (m):	10		
Local Shielding			
Building Site:	Low crops, x/H > 20		
Walls:	Heavy		
Flue:	Heavy		
Highest Ceiling Height (m):	5.181		
Building Configuration			
Type:	Detached		
Number of Stories:	Two		
Foundation:	Slab-on-Grade		
House Volume (m^3):	303.61		
Air Leakage/Ventilation			
Air Tightness Type:	Energy Tight (ACH=1.5)		
Custom BDT Data:	ELA @ 10 Pa.	163.92	cm^2
	1.5	ACH @ 50 Pa	
Mechanical Ventilation (L/s):	Total Supply: 28	Total Exhaust: 28	

Flue Size				
Flue #:	#1	#2	#3	#4
Diameter (mm):	0	0	0	0

Envelope Air Leakage Rate	
Heating Air Leakage Rate (ACH/H):	**0.152**
Cooling Air Leakage Rate (ACH/H):	**0.048**

Example-03



LOCATION:
This semi-detached house was built in Toronto, Ontario in 1943. The foundation is a mixed foundation (basement + slab-on-grade). There are two levels (Level 2 and Level 3) above grade. Arrange rooms in the following order on the worksheet.

Foundation (Level 1):

B (Basement)

Main Floor (Level 2):

K (Kitchen), Dining Room, and LR (Living Room)

Second Floor (Level 3):

BR3 (Bedroom-03), BR2 (Bedroom-02), and MB (Master Bedroom)

DESIGN CONDITIONS:
Winter indoor design temperature 72 °F.
Summer indoor design temperature 75 °F.
Inside conditions apply to all areas of the house

All ceiling heights are 8'.
Header heights are 12".
Basement wall extend 6' below grade.

SITE CONDITION:
Soil conductivity is high.
Water table is normal.

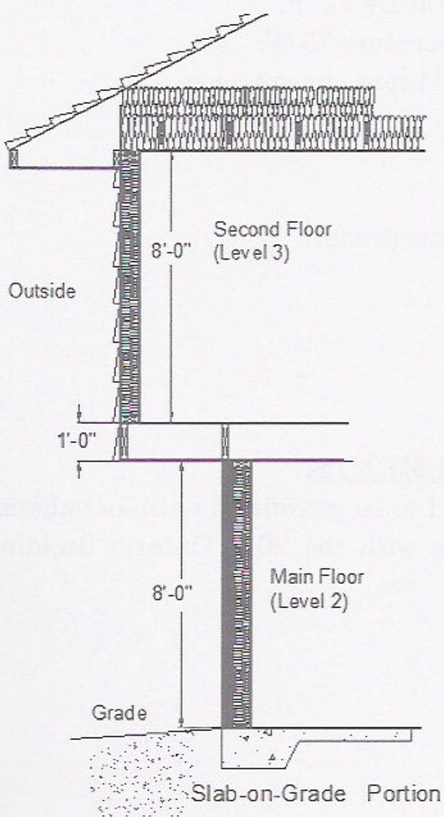
VENTILATION REQUIREMENTS:
The house will be considered to be retrofitted with an exhaust only system which complies with the 2010 Ontario Building Code.

FOUNDATION INFORMATION:

Basement foundation:
Concrete walls and floor
Interior surface of wall insulated over full height
Slab is uninsulated
(Use configuration BCIN_1)

Main Floor Slab-on-grade foundation:
Concrete walls and floor
No insulation, No skirt
Main floor brick veneer placed directly on concrete slab
(Use configuration SCN_2)

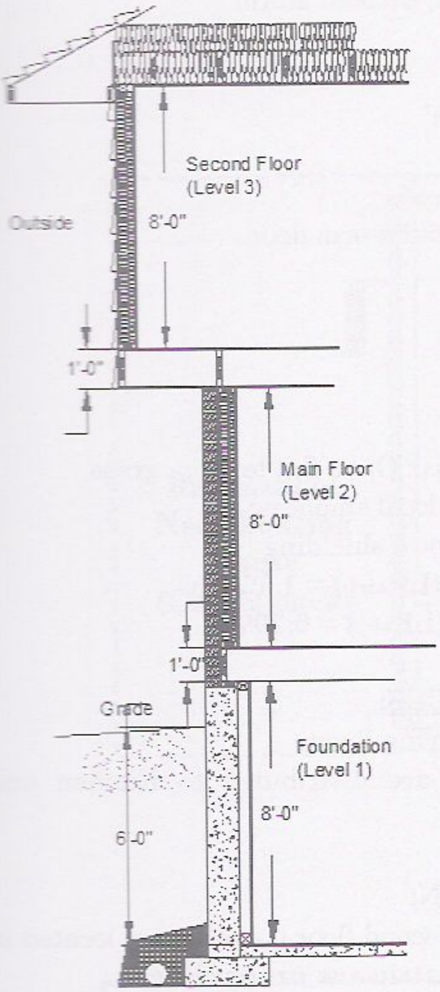
ENVELOPE CONSTRUCTION:



Second Floor (Level 3) Ceiling (Vented Attic)
- Outside air film (vented roof air space)
- 8" loose glass fibre fill insulation on top of ceiling joist
- 2 x 6" wood ceiling joists @ 16" o.c. filled with 5-1/2" wood shavings cavity insulation
- 1/2" gypsum board (interior finish)
- Inside air film

Second Floor (Level 3) Wall
- Outside air film
- Vinyl Siding (hollow backed)
- 3/8" plywood sheathing (generic softwood)
- 2" x 4" wood studs @ 16" o.c. filled with 3-1/2" wood shavings cavity insulation
- 1/2" gypsum board (interior finish)
- Inside air film

Second Floor (Level 3) Exposed Floor
- Outside air film
- Vinyl soffit (hollow backed)
- 1/2" plywood (generic softwood)
- 2" x 12" wood floor joists @ 16" o.c. with no cavity insulation
- 1/2" plywood (generic softwood)
- Hardwood flooring
- Inside air film



Basement Portion

Main Floor (Level 2) Header

- Outside air film
- Vinyl siding (hollow backed)
- 3/8" plywood sheathing (generic softwood)
- 1-1/2" lumber (wood, structural framing, spruce-pine-fir)
- 2" x 12" wood floor joists @ 16" o.c. with no cavity insulation
- Inside air film

Main Floor (Level 2) Wall

- Outside air film
- 4" fired clay brick
- 1" air space
- 3/8" plywood sheathing (generic softwood)
- 2" x 4" wood studs @ 16" o.c. filled with 3-1/2" wood shavings cavity insulation
- 1/2" gypsum board (interior finish)
- Inside air film

Main Floor (Level 2) Slab – Slab-on-Grade

- 4" concrete slab
- Linoleum tile
- Interior air film, floor (heat flow down)

Foundation (Level 1) Header

- Outside air film
- 4" Fired clay brick
- 1" air space
- 3/8" plywood sheathing (generic softwood)
- 1-1/2" lumber (wood, structural framing, spruce-pine-fir)
- 2" x 12" wood floor joists @ 16" o.c. without cavity insulation
- Inside air film

Foundation (Level 1) Wall

- Outside air film
- 8" concrete (150 lb/ft^3)
- 2" x 2" strapping without cavity insulation
- 1/2" Gypsum board (interior finish)
- Inside air film

Foundation (Level 1) Floor – Basement Floor

- 4" concrete slab (150 lb/ft^3)
- Interior air film, floor (heat flow down)

WINDOWS:

single glazed, operable wood, without storm
Interior shading of blinds

All windows have height of 4'

DOORS:

Solid wood 1-3/4" thick without storm door.

All doors are 7' in height.

AIR LEAKAGE:

Air tightness level: Loose
Building Site (Shielding class): Open flat terrain, grass
Sheltering level – Walls: No local shielding
Sheltering level – Flue: No local shielding
Heating air leakage rate (LR_{airh}) = 1.325/ h
Cooling air leakage rate (LR_{airc}) = 0.299/h

PEOPLE AND APPLIANCES:

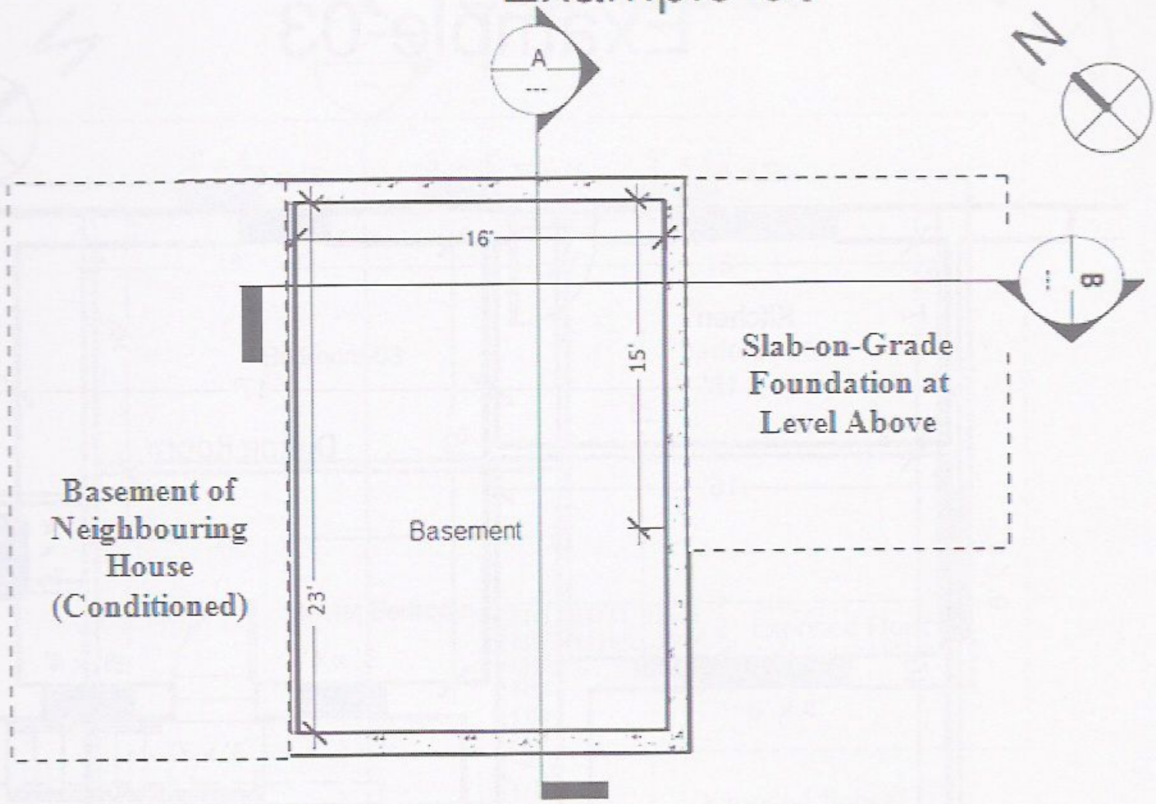
Allow for all people in the Living Room
Appliance and plug loads are distributed to Kitchen and Living Room

DUCTING INFORMATION:

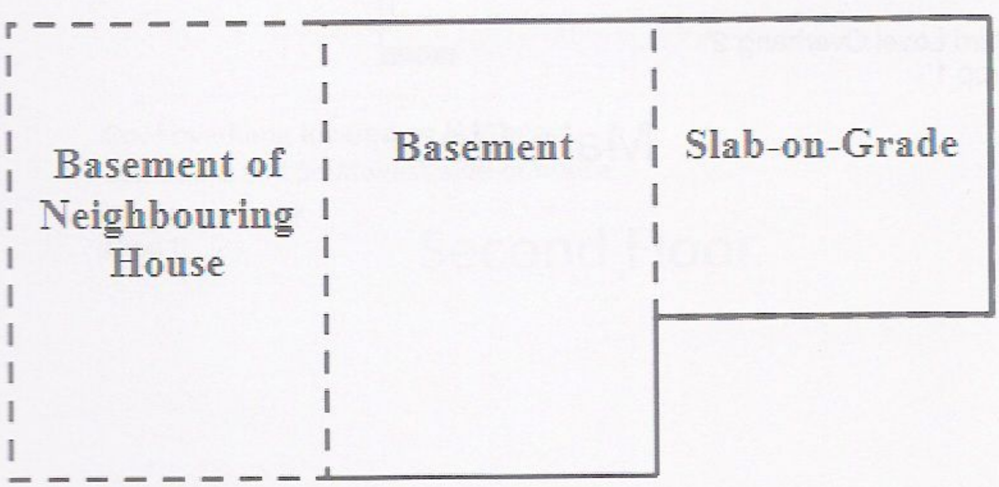
Ducts serving rooms in the second floor (Level 3) are located in the attic. **The ducts in the attic are uninsulated.**

Note A: Since the house still has three different facing directions for its exposed walls, the simplified version of solar correction table for normal procedure (Table 10) should be used for this house. (e.g. using the same solar correction for all facing directions of walls)

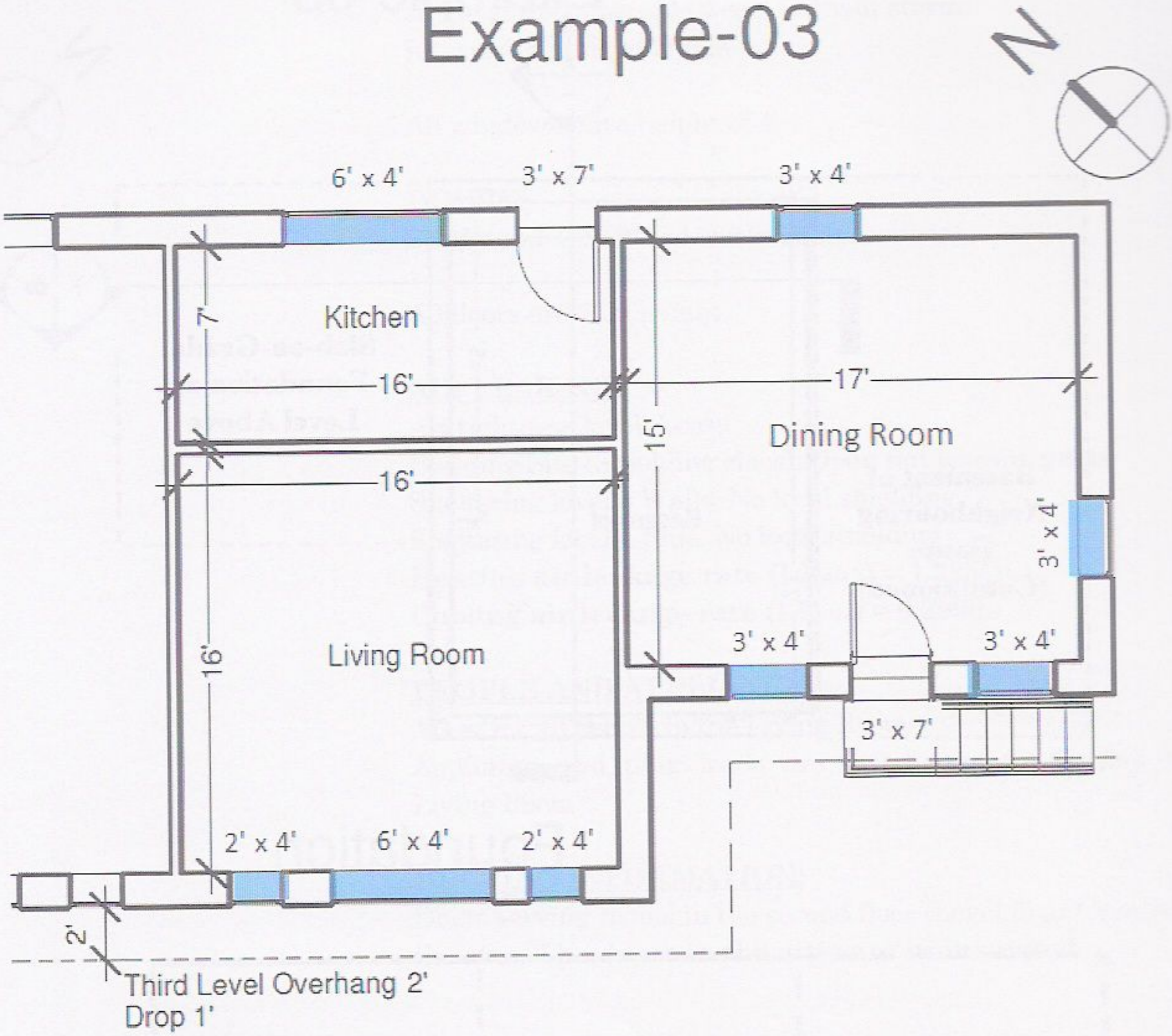
Example-03



Foundation

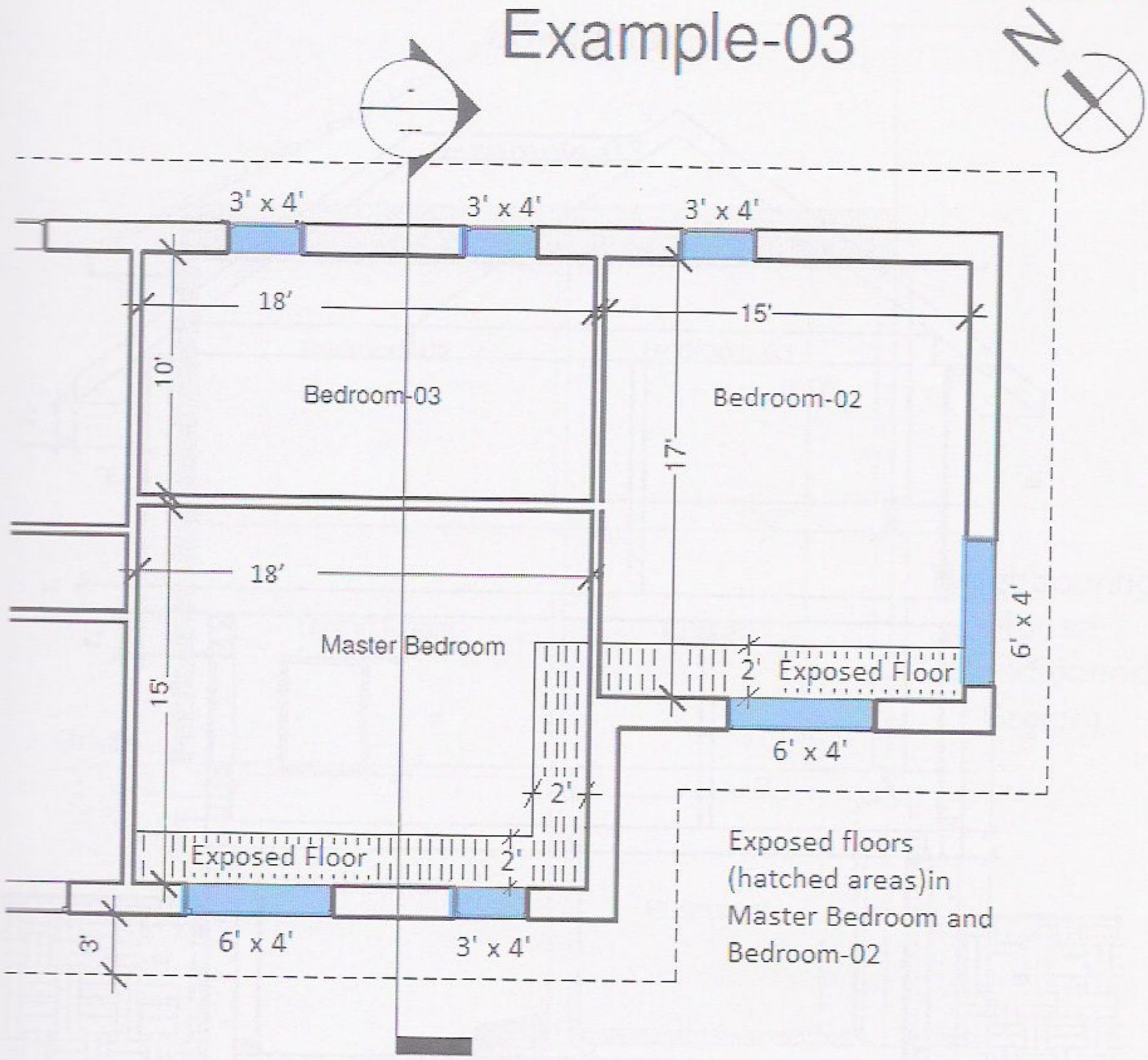


Example-03



Main Floor

Example-03

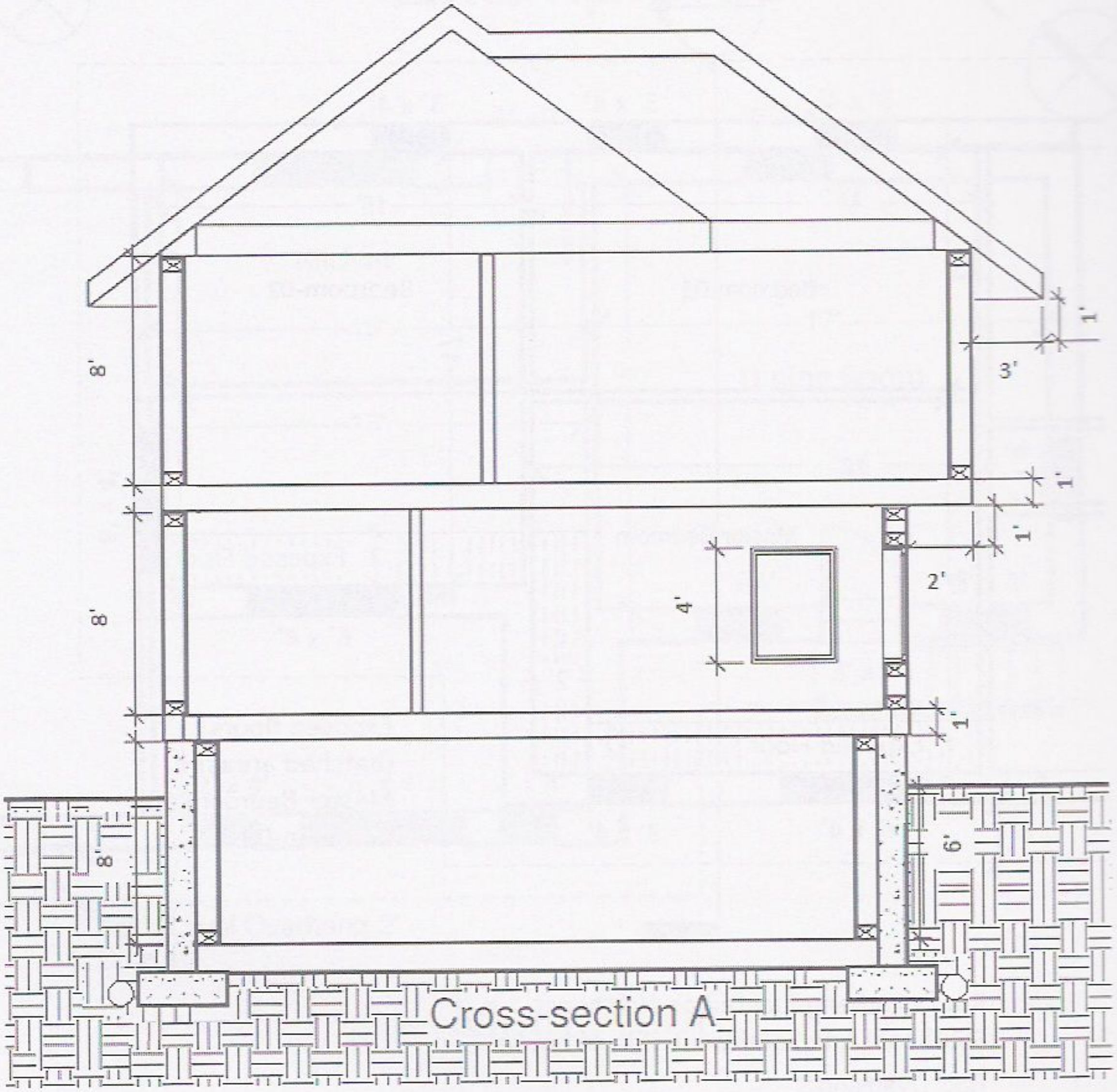


Roof overhang located on Northeast, Southeast and Southwest side of house

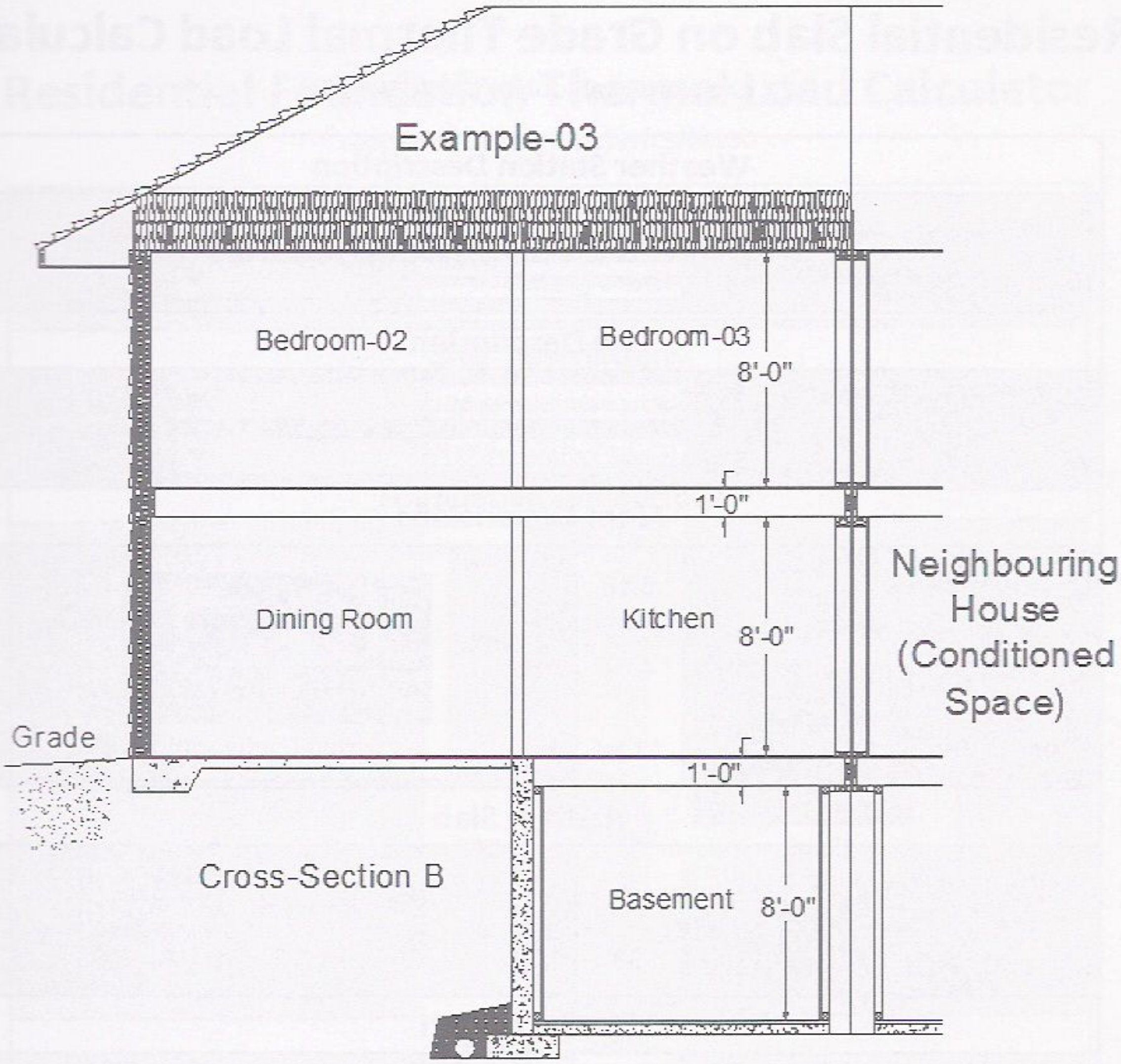
Roof Overhang 3'
Drop 1'

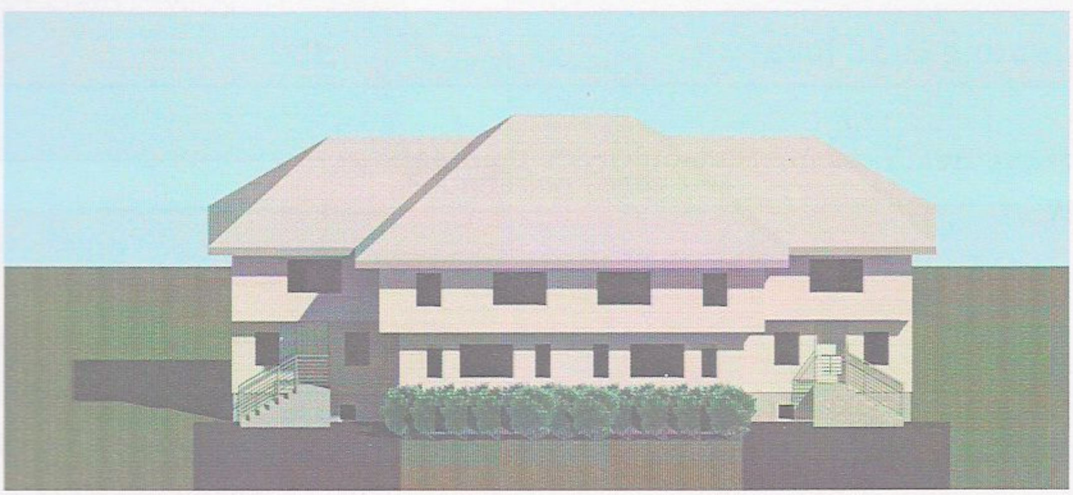
Second Floor

Example-03



Cross-section A

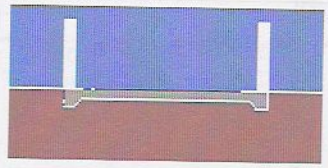

Example-03
Bedroom-02
Bedroom-03
8'-0"
1'-0"
Dining Room
Kitchen
8'-0"
Neighbouring House (Conditioned Space)
Grade
1'-0"
Cross-Section B
Basement
8'-0"



Residential Slab on Grade Thermal Load Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description	
Province:	Ontario
Region:	Toronto (city hall)
Site Description	
Soil Conductivity:	High conductivity: moist soil
Water Table:	Normal (7-10 m, 23-33 Ft)
Floor Dimensions	
Length (m):	5.18
Width (m):	4.57
Exposed Perimeter (m):	14.94
Radiant Slab	
Heated Fraction of the Slab:	0
Fluid Temperature (°C):	33
Design Month	
Heating Month	1
Results	
Heating Load (Watts):	**352**



Insulation Configuration

Conductive Heat Loss for Slab-on-Grade Foundation

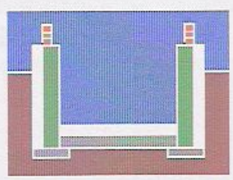
= 352 W

= 352 x 3.412 = 1201 Btuh

Residential Foundation Thermal Load Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description	
Province:	Ontario
Region:	Toronto (city hall)
Site Description	
Soil Conductivity:	High conductivity: moist soil
Water Table:	Normal (7-10 m, 23-33 Ft)
Foundation Dimensions	
Floor Length (m):	7.01
Floor Width (m):	4.88
Exposed Perimeter (m):	12.19
Wall Height (m):	2.44
Depth Below Grade (m):	1.83
Window Area (m^2):	0
Door Area (m^2):	0
Radiant Slab	
Heated Fraction of the Slab:	0
Fluid Temperature (°C):	33
Design Months	
Heating Month	1
Foundation Loads	
Heating Load (Watts):	1885


Insulation Configuration

Conductive Heat Loss for Basement Foundation

(includes Heat Loss from above grade basement walls)

= 1885 W

= 1885 x 3.412 = 6432 Btuh

Envelope Air Leakage Calculator

Supplemental tool for CAN/CSA-F280

Weather Station Description

Province:	Ontario
Region:	Toronto (city hall)
Weather Station Location:	Open flat terrain, grass
Anemometer height (m):	10

Local Shielding

Building Site:	Open flat terrain, grass
Walls:	No local shielding
Flue:	No local shielding
Highest Ceiling Height (m):	6.096

Building Configuration

Type:	Semi-Detached
Number of Stories:	Two
Foundation:	Full
House Volume (m^3):	412.26

Air Leakage/Ventilation

Air Tightness Type:	Loose (Pre-1945) (ACH=10.35)	
Custom BDT Data:	ELA @ 10 Pa. 1444.4	cm^2
	10.35	ACH @ 50 Pa
Mechanical Ventilation (L/s):	Total Supply: 0	Total Exhaust: 30

Flue Size

Flue #:	#1	#2	#3	#4
Diameter (mm):	0	0	0	0

Envelope Air Leakage Rate

Heating Air Leakage Rate (ACH/H):	**1.325**
Cooling Air Leakage Rate (ACH/H):	**0.299**

5 Glossary of Terms

Residential and Small Commercial

Terms in italics are defined elsewhere in this glossary.

Absolute Humidity or Humidity Ratio -
the mass of water divided by the mass of air containing the water vapour

Air Barrier -
any material used as to block the flow of air

Air Change -
the sum of *air leakage* and *ventilation*

Air Change Rate -
the number of times in one hour that the air is replaced in a space. Unit: air changes per hour (AC/h). 1 AC/h is the air flow rate which in 1 h would move a volume of air equal to the space.

Air, Combustion -
the air required for satisfactory combustion, including excess air, for a fuel burning *appliance*

Air, Exhaust -
the air mechanically removed to the outdoors from a space, by such devices as kitchen fans, dryers, central vacuum cleaners, and not reused

Air, Flue Gas Dilution -
the ambient air that is admitted to a *venting system* at the draft hood, *draft* diverter or *draft regulator*

Air Leakage -
the uncontrolled exchange of air between the interior and exterior environments through unintentional openings in the *building envelope* under the influence of wind and buoyancy (*stack effect*) pressures. Infiltration and exfiltration are both components of air leakage. See Convection and Thermal Buoyancy.

Exfiltration -
uncontrolled air flow from inside to outside the building through cracks and gaps

Infiltration -
uncontrolled air flow from outside to inside the building through cracks and gaps

Air, Make-up -
outdoor air supplied to replace *exhaust air*, eg, by *infiltration*, *make-up air* duct, supply fan etc. It does not include air entering the house as *combustion air* or to replace *exfiltration* air.

Air, Outdoor -
air from the external atmosphere, not previously circulated in the building. It is usually less contaminated than indoor air.

Air, Recirculation –
air removed from a space and then returned heated, cooled, humidified etc.

Air, Relief -
air mechanically removed, passively exiting, or exfiltrating from the house to reduce mechanically induced pressurization (opposite of *make-up air*)

Air, Return -
recirculation air being removed from a space

Air, Supply -
recirculation air, with or without mixed *ventilation* air, injected into a space

Air / Vapour Barrier -
any material used to block the flow of air and water vapour

Air, Ventilation (Supply) -
outdoor air intentionally supplied by mechanical means to a *conditioned space*

Apparent Sensible Effectiveness (ASE) -
the term used in the CSA C439M standard for testing *HRV*s to describe the temperature rise of *out-door air* passing through an *HRV*. The effectiveness includes the effect of motor heat gain, cross-leakage gain and casing gain. It is usually numerically higher than the *sensible recovery efficiency* of the HRV. When the flows of indoor and outdoor air through the HRV are equal, it equals the temperature rise of the outdoor air divided by the temperature difference between indoor and outdoor air entering the HRV, expressed as a percentage.

Appliance -
a device to convert energy from fuel into heat energy, and includes any component, control, wiring, piping or tubing required to be part of the device

ASHRAE -
American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

Aspect Ratio -
the ratio of the width to the depth of a duct

B-Vent -
a labelled, double-walled sheet metal *chimney* assembly, consisting entirely of factory-made parts, designed as "class B" according to the Gas Installation Code CGA B149

Backdrafting (Back Spillage) -
flow reversal in a flue serving a fuel-fired *appliance*: the combustion products normally flowing up the flue are forced to reverse their course and discharge into the space occupied by the appliance

Barometric Damper -
See Draft Regulator.

Blower -
a fan used to force air under pressure

Boiler -
an *appliance* supplying hot liquid or vapour

Branch Duct -
See Duct, Branch.

British Thermal Unit (Btu) -
the quantity of heat required to raise the temperature of 1 lb of water 1 Fahrenheit degree.
1 Btu/h = 0.2931W
1 W = 3.412 Btu/h

Building Envelope -
the surface formed by all components of the building which enclose the *conditioned space*

Burner -
a device for the introduction of fuel, with or without air or oxygen, into the combustion zone for ignition

Natural draft:
the burner is not equipped with a fan or *blower*.

Fan assisted:
the *combustion air* is supplied by a mechanical device such as a fan or *blower* at sufficient pressure to overcome the resistance of the burner only.

Forced draft:
the *combustion air* is supplied by a mechanical device such as a fan or *blower* at sufficient pressure to overcome the resistance of the burner and the *appliance*.

cfm, CFM -
cubic feet per minute, a measure of air flow
1 cfm = 0.472 L/s or,
conventionally, 1 cfm = 0.5 L/s

CFS -
Commercial Fact Sheet

Chimney -
a primarily vertical shaft enclosing at least one *flue*

Circulation Fan -
usually the main *furnace blower* in a forced air system. Can be any ducted fan used to distribute *recirculation air* throughout the house. When the *ventilation* system is coupled to the forced air system this blower is required to be operable independently of the *furnace* heating and cooling cycle.

Coaxial Vent -
a combustion *appliance venting system* consisting of an inner pipe exhausting *products of combustion* within an outer pipe drawing in *combustion air*

Combustion Air -
See Air, Combustion.

Combustion Products or **Gases -**
the constituents resulting from combus-tion of fuel with the oxygen of the air and includes inert gases that are part of the air, but not excess air

Comfort Zone -
the range of effective temperature over which a majority (50% or more) of adults feel comfortable

Condensation -
the process of changing a vapour into liquid by the extraction of *latent heat*

Conditioned space –
any interior portion of the building that is intended to be heated, cooled or ventilated

Conductance, Thermal -
the time rate of heat flow through unit area of a body, per unit temperature difference. Often called U-Value.
Units: Btu/(h ft² °F) or W/(m² °C)

Conduction, Thermal -
the process of heat transfer through a material from the hotter side to the cooler

Convection -
the transfer of heat that takes place within moving gases and liquids. An example is the heat carried by air after it has passed over a heating coil or heat exchanger in a heating unit. In a cavity in a wall, air heats and expands next to the warmer side, becomes lighter and rises. It is continuously replaced by a flow of cooler air from the opposite side. When the warmed air reaches the cooler side, it passes heat to the surface there and the circulation continues.

Crawl Space -
a shallow space below the living quarters of the basementless part of a house, normally enclosed by the foundation wall

CSA -
Canadian Standards Association

Cubic Feet per Minute (cfm) -
Imperial unit of airflow. 1 cfm = 0.472 L/s and 1 L/s = 2.12 cfm. In common practice, using 1 cfm = 0.5 L/s and 1 L/s = 2 cfm is close enough, though the error is technically about 6 %.

Damper -
a valve or plate regulating the flow of air in a duct

Damper, Barometric –
See Draft Regulator.

Degree-Day -
For each day with a mean temperature below 18 °C (65 °F) the number of degree-days is this difference. These can be added up for a month or for a heating season. Used in calculating heating energy consumption.

Delta T (ΔT) -
the temperature difference across a building component: for heating calculation, *IDT - ODT* ; for cooling, *ODT - IDT*

Depressurization -
See Pressure, Negative.

Design Temperature (2.5% basis) -
the temperature used for sizing heating or cooling equipment. When actual temperatures go beyond the design temperatures, and there is no excess capacity in the equipment, thermal momentum will carry the building through these conditions for short periods, or a small degradation of comfort conditions can be expected.

Winter Design Temperature -
based on a 10 year average, the lowest sustained temperature that might be expected in normal winter conditions. The coldest month is January and 2.5% of the time in January the outdoor temperature may fall below the design temperature, but usually for only a short time.

Summer Design Temperature -
based on a 10 year average, the highest sustained temperature that might be expected in normal summer conditions. The warmest month is July and 2.5% of the time in July the outdoor temperature may rise above the design temperature, but usually for only a short time.

Design Temperature Difference (DTD) -
the difference between the indoor *design temperature* and the outdoor *design temperature*

Dew Point -
the saturation temperature at which condensation of water vapour to visible water takes place. An example is the sweating on a glass of ice water. The cold glass reduces the air temperature below its dew point, and the moisture that condenses forms beads of water on the glass surface.

Diffusor -
the slotted or bladed guard at the room end of a *branch duct*, which may be equipped with a means of adjusting the aim of the flow of air

Dilution Air -
See Air, Flue Gas Dilution.

Direct Vent (sealed combustion) -
applies to a type of fuel-fired *appliance* that takes its *combustion air* directly from the outdoors via a sealed passageway, and ejects its *combustion gases* outdoors as well, through an independent sealed *vent*, without ever using the indoor air of the building for combustion or venting

Distribution Effect -
an increase to the *stack effect* resulting from the *depressurization* of the basement due to *return air* being sucked into leaks in a joist distribution system or through basement return air inlets

Draft -
(1) the pressure difference which causes a current of air or gases to flow through a *flue*, *chimney*, heater or space;
(2) the flow of air, or *combustion products*, or both, through an *appliance* and its *venting system*;
(3) an uncomfortable localized feeling caused by one or more factors of high air velocity, low ambient temperature, or direction

of air flow, whereby more heat is withdrawn from a person's skin than is normally dissipated

Draft Control Device -

either a *draft hood* or a *draft regulator*

Draft Hood -

a draft control device having no moveable or adjustable parts. It may be built into or attached to an *appliance* or made part of a *vent connector*, and is designed to:
(1) assure ready escape of *flue gases* from the combustion chamber if there is either no *draft* or stoppage downstream of the draft hood; (2) prevent a *back-draft* from entering the combustion chamber of the *appliance*; and (3) reduce the effect of stack action of a *chimney* or *vent*, when the *appliance* operates.

Draft, Induced –

a *mechanical draft* where the fan or *blower* is in the *flue gas* stream

Draft, Mechanical -

a *draft* produced by a mechanical device such as a fan, *blower* or aspirator

Draft, Natural -

a *draft* where the *combustion air* is supplied from within the building and the *products of combustion* are conveyed to the outdoors through a *chimney* or *B - vent*. This type of draft relies on *thermal buoyancy* to vent the combustion products. The upward force created by the buoyancy must be greater than any resisting forces in the *building envelope*. The force generated by the thermal buoyancy is proportional to the difference between the outdoor temperature and the flue gas temperature. This type of draft may be reversed, resulting in combustion spillage, if there is excessive negative pressure in the house or insufficient flue gas temperature.

Draft Regulator (Barometric Damper) -

a draft control device intended to stabilize the *natural draft* in an *appliance* by admitting room air to the *venting system*. A double-acting draft regulator has a balancing *damper* free to move in either direction.

Dry Bulb Temperature -

the temperature of air indicated by an accurate thermometer. This is the usual temperature to which people refer, but it is called "dry bulb" when it is necessary to distinguish it from *wet bulb temperature*. These two temperatures are required for accurate calculation of *relative humidity*.

Duct, Branch -

a passageway carrying air to or from only one *register* or *grille*

Duct, Trunk -

a passageway carrying the air to or from two or more *branch ducts*

Effective Length -

in duct design, the length of a particular duct system path, equal to the total of the actual duct length and the *equivalent lengths* of the fittings in the flow path. Used in duct design

Equivalent Length -
The length assigned to a duct fitting, expressed as the number of feet of straight smooth round duct of the same diameter as the fitting, which would have the same resistance to airflow

Equivalent Temperature Difference (ETD) -
for cooling load calculations, the actual temperature difference across an opaque building assembly modified for the effect of the sun, according to the assembly's orientation, material, colour, and time of day.

Energy recovery ventilation (ERV)-
The energy recovery process of exchanging the energy contained in normally exhausted building or space air and using it to treat the incoming outdoor ventilation air in residential and commercial HVAC systems.

ESP -
External Static Pressure. See Pressure, External Static.

ETD –
Equivalent Temperature Difference

Evaporation –
the process of changing a liquid into a vapour by adding *latent heat*

Exfiltration -
See Air Leakage.

Exhaust Air -
See Air, Exhaust.

External Static Pressure -
See Pressure, External Static.

Feet per Minute (fpm) -
Imperial unit of air velocity. 1 fpm = 0.00508 m/s and 1 m/s = 196.9 fpm. In common practice, using 1 m/s = 200 fpm is close enough, as the error is only about 1.6 %.

Flue -
an enclosed passageway for conveying *flue gases*

Flue Effect -
the *infiltration* caused by the suction created by the rapid rising of *combustion gases* in a *chimney* using *natural draft*

Flue Gas Dilution Air -
See Air, Flue Gas Dilution.

Flue Gases -
These are *combustion products* and excess air.

Fluorescent -
of a light source which provides light from an electrically excited but relatively cool coating

FMS –
Flow Measuring Station

Forced Draft -
See Burner, Forced Draft.

Forced Draft Burner -
See Burner, Forced Draft.

Formaldehyde -
a colourless, pungent gas used in solution as a strong disinfectant and preservative and in the manufacture of synthetic glues and UFFI

fpm, FPM -
feet per minute, a measure of air velocity 1 fpm = 0.00508 m/s or, conventionally, 1 m/s = 200 fpm

Fresh Air -
See Outdoor Air.

Furnace -
an indirect-fired, flue-connected, space-heating *appliance*, using warm air as the heating medium, and usually having provision for the attachment of ducts

Furnace Room -
an enclosed space that contains a *furnace* and usually separates an open basement from the furnace

FWA –
Forced Warm Air

Grade -
the lowest of the average levels of finished ground adjoining each exterior wall of a building. Localized depressions such as for vehicle or pedestrian entrances need not be considered in the determination of average levels of finished grade.

Grille –
the slotted guard at the room end of a *branch duct*. Usually non-adjustable, and spoken of in reference to return air ducts.

Habitable Space -
space designed for human occupancy, such as a bedroom, living room, dining room, kitchen, family room, recreation room, or den.

Head Drop -
The vertical distance between the lower edge of an eave and the top edge of the outer surface of the window glass. This is the vertical component, which, with *overhang*, determines shading of a window.

Heat Loss Factor (HLF) -
for basements, a factor relating heat loss to the temperature difference and to dimensions which depend on the part of the building envelope being considered:
For walls below grade, its units are Btu/(h ft °F) or W/(m °C), where the length is the perimeter of the below-grade portion of the wall.
For floors below grade, its units are Btu/(h ft² °F) or W/(m² °C), where the area is the area of the below-grade floor.
These factors come from tables which take into account the depth below grade and the insulation added to the bare wall.

Heat Reclaimer -
a device installed externally or internally to a *venting system* to extract heat from *flue gases*

Heat Recovery Ventilator (HRV) -
a factory assembled unit incorporating a means to circulate air for *ventilation* and a means to transfer heat between the incoming and outgoing air streams

HLF –
Heat Loss Factor

Hood -
a terminal in the exterior wall, floor or roof for the *outdoor air* inlet or the *exhaust air* outlet

HRAI -
Heating, Refrigeration and Air Conditioning Institute of Canada

HRV -
Heat Recovery Ventilator

Humidity Ratio -
See Absolute Humidity.

HVI -
Home Ventilating Institute

IAQ -
Indoor Air Quality

IDT -
Indoor *Design Temperature*

Incandescent -
of a light source which provides light from a white-hot electrically heated filament

Inches Water Column (or Gauge) -
a measure of small pressure differences, equivalent to that obtained by observing the difference in height of the water levels in a U-tube whose ends are connected to the places having different pressures. Unit: in w.c. or Pa 1 in w.c. = 249 Pa, or, conventionally, 1 in w.c. = 250 Pa.

Incident Radiation -
solar radiation as it strikes a surface

Induced Draft -
See Draft.

Infiltration -
See Air Leakage.

Interpolation -
finding a value from a table or list when the value used for reference falls between a pair of reference values of the table

Laminar Flow -
a predictable parallel flow of air particles in a duct, occurring only at very low velocities, and offering less resistance than *turbulent flow*

Latent Heat -
the energy involved in a change of state without a change in temperature. For example, to evaporate 1 lb of water to water vapour takes 970 Btu and condensing 1 lb of water vapour to water will release 970 Btu. All this happens while the temperature remains steady.

Litres per Second (L/s) -
metric unit of airflow. 1 L/s = 2.12 cfm and 1 cfm = 0.472 L/s. In common practice, using 1 L/s = 2 cfm and 1 cfm = 0.5 L/s is close enough, though the error is technically about 6 %.

Make-up Air -
See Air, Make-up.

Mechanical Draft -
See Draft.

Minimum Ventilation Capacity (MVC) -
in the CSA F326 standard, a capacity set by "room count", ie, 5 L/s per room but 10 L/s for the master bedroom, and 10 L/s for a basement area exceeding 2/3 of the total basement area. This is the same as the OBC's *Total Ventilation Capacity*.

Mixed Air Temperature (MAT) -
When *ventilation* is used, the temperature of the mixture of the *return air* and the *outdoor air* used for ventilation

Natural Draft -
See Draft.

Natural Ventilation -
outdoor air supplied to a *habitable space* by natural forces through intentional openings such as open doors and windows, and by *air leakage* through unintentional cracks or holes.

NBC -
National Building Code of Canada, usually updated in years ending in 0 and 5, issued by the Canadian Commission on Building and Fire Codes, National Research Council of Canada

OBC -
Ontario Building Code, usually updated after each edition of the *NBC* (National Building Code), issued by the Ontario Buildings Branch, Ministry of Housing of Ontario

ODT -
Outdoor *Design Temperature*

OEL -
Ontario Electrical League

Outdoor Air -
See Air, Outdoor.

Overhang -
the horizontal distance an eave extends outward past the outer surface of the window. This is the horizontal component which, with *head drop*, determines shading of a window.

Package Unit -
an *appliance* supplied as a complete unit including controls and integral wiring

Packaged Ventilator -
a factory assembled unit which has a means to supply *ventilation air* and/or to remove *exhaust air*, intended for continuous or intermittent operation, such as *HRV*s and bathroom fans

Partition -
any wall or floor separating conditioned zones in a commercial building

PEFC -
Principal Exhaust Fan Capacity, in the OBC, a flow determined by the number of bedrooms

Power Venter -
a device to provide *mechanical draft* installed between the *appliance* and the *vent* termination

Pressure Drop -
the *static pressure* loss caused by air flow through a duct, filter coil, *HRV* core, etc

Pressure, External Static (ESP) -
The negative *static pressure* in a *return air* plenum is interconnected with the positive static pressure in the supply plenum of a unit such that when they are added together, they become the total external static pressure of the unit. The unit external static pressure is the motive force that the blower will exert, after overcoming the internal resistance of the filter and casing, to propel the air to be circulated through the supply and return air ducts.

Pressure, Negative (depressurization) -
the condition of lower air pressure inside the house than outside. It happens when the amount of air removed from the house exceeds the amount supplied by mechanical or other means. *Outdoor air* is sucked in through any openings in the *building envelope*, which may include the *chimney*.

Pressure, Positive (Pressurization) -
the condition of higher air pressure inside the house than outside. It happens when the amount of air supplied to the house exceeds the amount removed by mechanical or other means. Excess air is forced out through any openings in the *building envelope*.

Pressure, Static -
the pressure available between the inside and outside of a duct; a measure of pressure available from a fan to move a given amount of air or the pressure required to use or deliver a given amount of air across a resistance (for example, a filter, coil, length of duct, etc.)

Pressurization -
See Pressure, Positive.

Principal Exhaust Fan -
a fan intended to be able to remove air from a home continuously. An *HRV* can be a principal exhaust fan.

Products of Combustion -
See Combustion Products.

R-2000 -
A Canadian performance standard for efficiency in housing including testing airtightness using pressurizing equipment

R-Value -
See Resistance, Thermal.

Radiation -
the transmission of heat energy which occurs by means of electro-magnetic waves whenever two surfaces at different temperatures face each other

Recirculation Air -
See Air, Recirculation.

Register -
the slotted guard at the room end of a *branch duct*, equipped with a *damper* or other means of regulating and/or aiming the flow of air

Relative Humidity -
the ratio of the amount of water vapour in the air to the greatest amount that could be in it at the same temperature, expressed as a percent

Relief Air -
See Air, Relief.

Resistance, Thermal -
often called R-Value, the reciprocal of thermal conductance (ie, R = 1/U). Units: (h ft^2°F)/Btu or (m^2 °C)/W. The resistances of adjacent components of an assembly, eg, a wall, may simply be added to find the total resistance of the assembly. Heat loss or gain due to conduction is then the product of the area and temperature difference, divided by the R-Value.

Return Air -
See Air, Return.

Return Air Ceiling Plenum -
the space above the finished ceiling, and below the roof or floor above, used for the collection of air from the space below the ceiling for cycling through the conditioning system

Safety Limit Control -
a safety control intended to prevent an unsafe condition of temperature, pressure or liquid level

SC -
See Solar Correction

Sealed Combustion -
See Direct Vent.

Sensible Heat -
heat that will change the temperature of a substance without changing its state. Sensible heat is measured with a thermometer. Water that is heated from 20°C (68°F) to 35°C (95°F) does not change its state. It remains a liquid. Because this change in temperature can be read with a thermometer, the heat involved is sensible heat. The reverse is also true: if the water is cooled, the amount of heat removed is sensible heat.

Sensible Recovery Efficiency (SRE) -
the term used in the CSA C439M standard for testing *HRVs* to describe the net energy recovery during winter heating conditions. It is corrected for the effect of motor heat gain, defrost energy, cross-leakage gain and other effects like casing gain. It is usually numerically lower than the *apparent sensible effectiveness* of the HRV.

Shading Factor (SF) -
a geometric factor, dependent on latitude and orientation, used to calculate the shading effect of an *overhang* on a window

SI -
the official international abbreviation of the name for the modern metric system of measurement. It stands for Le Système international d'unités.

SMACNA -
Sheet Metal and Air Conditioning Contractors' National Association

Solar Correction (SC) -
an amount to be added (though the number is sometimes negative) to the cooling ΔT to allow for the solar radiation effect and mass effect for walls and roofs

Solar Heat Gain Factor (SHGF) -
for cooling load calculations, a factor expressing heat gain per unit area across a glazed building assembly, according to the assembly's orientation, the construction of the building, and the time of day

Solar Radiation -
the energy arriving in a direct line from the sun in the form of light and heat, warming any object in its path

Specific Heat -
the quantity of heat required to change the temperature of a substance by one degree. 1 Btu is required to change the temperature of 1 lb of water 1°F, or in the SI, 1.16 Wh is needed to change the temperature of 1 kg of water 1°C.

Stack Effect -

The tendency of warm air which has risen to the top in a building (because it is lighter) to escape through cracks and be replaced by colder air from outside which infiltrates through lower openings. The overall result is a continuous flow, with *exfiltration* occurring upstairs and *infiltration* occurring downstairs. At some point, where the air flow changes from an outward to an inward direction, there is no pressure difference between inside and outside. This can be described as a flat surface cutting across the building and dividing it into two parts: one with high pressure and one with low pressure, relative to the outdoors. This dividing plane is known as the "neutral pressure plane".

Static Pressure -

See Pressure, Static

Supplemental Exhaust -

the exhaust required in addition to the *principal exhaust fan* capacity (PEFC) to equal the *total ventilation capacity* (TVC). It may be provided by one or more of a higher speed of the principal exhaust fan or the *HRV*, or kitchen, range hood, bath or water closet fans.

Supplementary Heating -

may be used in finished basements and/or basement walk-out areas; may be supplied by any type of thermostatically controlled heating source

Supply Air -

See Air, Supply.

Terminal Velocity -

for a diffuser, a velocity of about 50 fpm, used to define the extent of the throw of the diffuser

Thermal Buoyancy -

the result of a gas being warmer than a larger body of gas to which it is connected. The warmer body of gas is lighter and will seek to rise relative to the larger body. In houses it is evident in the action of *natural draft chimneys* and in the *stack effect*.

Thermal Conductance -

See Conductance, Thermal.

Thermal Resistance -

See Resistance, Thermal.

Thermal Storage -

the delayed release of heat absorbed from *solar radiation* by objects within a *conditioned space* and by the surfaces enclosing it

Ton of refrigeration (tons) -

a unit of cooling power that is used to express cooling capacity of refrigeration and air conditioning equipment

1 ton = 12,000 Btu/h

1 ton = 3.517 kW

Total Pressure -
although a non-existent pressure, this term expresses the sum of *static* and *velocity pressures.*

Total Ventilation Capacity (TVC) -
in the *OBC*, the minimum combined capacity of the *ventilation* system(s) installed, calculated by a "room count": 5 L/s per room but 10 L/s for the master bedroom, and 10 L/s for a basement area which exceeds 2/3 of the total basement area. This is the same as the CSA F326 standard's *Minimum Ventilation Capacity.*

Trunk Duct -
See Duct, Trunk.

Turbulent Flow -
an irregular swirling flow of air particles in a duct, occurring at all but very low velocities, and offering more resistance than *laminar flow*

TVC -
Total Ventilation Capacity

Type B Vent -
See B-Vent.

U-Value -
See Conductance, Thermal.

UFFI -
Urea Formaldehyde Foam Insulation, a form of insulation foamed into place in cavities until much alarm was raised on its suspected harmful effects on human health

ULC -
Underwriters' Laboratories of Canada, Scarborough, Ontario

VAV (Variable Air Volume) -
an air distribution system used in commercial projects where a constant volume of air circulates through the ductwork, but controlled variable amounts are bled to the spaces to be conditioned

Velocity Pressure -
a pressure equivalent for the kinetic energy of a moving air stream, convertible to *static pressure*

Vent -
that portion of a *venting system* designed to convey *flue gases* directly to the outdoors from a *vent connector* or an *appliance* when a vent connector is not used

Vent Connector -
that part of a *venting system* that conducts the *flue gases* from the *flue* collar of an *appliance* to a *chimney* or *vent*, and may include a *draft control device.*

Ventilation -
the controlled exchange of air between the interior of a building and its surroundings. It can be provided by bathroom and kitchen exhaust fans, dryer vents and all other mechanical devices that expel air or allow air into the structure.

Ventilation Effect -
the *infiltration* caused by the suction created by operation of exhaust devices such as bathroom fans, clothes dryers and central vacuum systems

Ventilation Supply Air -
See Air, Ventilation Supply.

Venting System -
a system for removing *flue gases* to the outdoors by means of a *chimney, vent connector, vent* or a natural or mechanical exhaust system

Watt -
the *SI* unit of power
1 W = 3.412 Btu/h

Wet Bulb Temperature -
the temperature indicated by the wet-bulb thermometer of a psychrometer. Used, with the dry bulb temperature, for calculation of *relative humidity*

Wind Effect -
the *infiltration* on the windward side of a building and the *exfiltration* on the leeward side, caused by pockets of higher and lower pressure outside the building when the wind blows

List of Abbreviations

The following abbreviations are used in this Manual:

A = Area of irregular foundation

ACH = air changes per hour

A_F = Floor area of the building assembly

App. = Appendix

ATRE = adjusted total recovery efficiency of the HRV/ERV, expressed as a fraction, or zero if there is no ATRE reported

BDT = Blower door test

BLDG = Building

BTU = British thermal unit

E = apparent sensible effectiveness of the HRV/ERV, expressed as a fraction, or zero if there is no heat recovery

ELA = Equivalent Leakage area

ERV = Energy recovery ventilator

HLbvent = Building Ventilation Heat loss

HGbvent = Building ventilation heat gain

HLrvent = Room ventilation heat loss

HGrvent = Room ventilation heat gain

HGleak = Building air leakage heat gain

HGsp = Sensible heat gain due to people

HGlae = Internal heat gain due to lights, appliances and electrical plug loads

HLleak = Building air leakage heat loss

HLclevel = Level conductive heat loss

HRV = heat recovery ventilator

ISF = Internal shading factor

ICFs = Insulated concrete forms

IDT = Indoor design temperature

L = Equivalent length of irregular foundation

LF = Level factor

LRairc = Envelope air leakage rate for cooling (output from the AIM2 spreadsheet)

LRairh = Envelope air leakage rate for heating (output from the AIM2 spreadsheet)

LVL = Level

MVC = Minimum Ventilation capacity

ODT = Outdoor design temperature

P/Peri. = Perimeter

P_E = Exposed perimeter

PVC = the principal or continuous *ventilation* rate as determined by the designer in accordance with CAN/CSA-F326 or local building code requirements, L/s

Qvr = Room ventilation rate

RH = Relative Humidity

SC = Solar correction

HRAI Residential Heat Loss and Heat Gain Calculations		Page 1 of ____
	BUILDING LOCATION	
	Model	Site
	Address	Lot
	City and Province	Postal Code

SUBMITTED FOR		**DESIGNED/SUBMITTED BY:**	
Name		Name	
		Company	
Address		Address	
City and Province	Postal Code	City and Province	Postal Code
Telephone		Telephone	
E-mail		E-mail	

FOR DESIGNER'S USE:			
Signature:	Date Prepared (MM/DD/YY)	HRAI #	Other Certification # (e.g. BCIN)

SECTION A	**BUILDING CONSTRUCTION DETAILS**		
Plan & Drawing No:			
Attachment:		Front facing:	Assumed ☐ Yes ☐ No
No. of Stories		Air tightness:	Assumed ☐ Yes ☐ No
Weather location	Ventilated ☐ Yes ☐ No	Local Shielding:	
HRV Model	☐ N/A	Internal Shading:	Occupants:
		Units: ☐ Imperial ☐ Metric	

Building Envelope Assemblies

Above Grade Walls		**Windows & Skylights**	
Structure:		Structure:	
Structure:		Structure:	
Structure:		Structure:	
Structure:		Structure:	
Below Grade Walls		**Headers**	
Structure:		Structure:	
Structure:		Structure:	
Ceilings		**Floors on Soil**	
Structure:		Structure:	
Structure:		Structure:	
Doors		**Exposed Floors**	
Structure:		Structure:	
Structure:		Structure:	

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HRAI Residential Heat Loss and Heat Gain Calculations Page 2 of ____

SECTION B — DESIGN CONDITIONS

HEAT LOSS		HEAT GAIN	
Outdoor Design Temperature Heating(ODT)	____ °F / °C	Outdoor Design Temperature Cooling (ODT)	____ °F / °C
Indoor Design Temperature (IDT)	____ °F / °C	Indoor Design Temperature (IDT)	____ °F / °C
Mean Soil Temperature	____ °F / °C	North Latitude	____ °
		Summer Mean Daily Temperature Range	____ °F / °C
Building Volume (Vb)	ft^3 / m^3	Building Conditioned Area	ft^2 / m^2

HRV Apparent Sensible Effectiveness = (insert N/A if no HRV/ERV installed)

Ventilation System:

☐ Case #1: Exhaust Only System ☐ Case #2: Direct Ducted System ☐ Case #3: Central Forced Air System

SECTION C — ROOM HEAT LOSS / HEAT GAIN SUMMARY

Level	Room Name	Total Heat Loss Calculated Section 16 Btuh/W	Total Heat Gain Calculated Section 17 Btuh/W	Level	Room Name	Total Heat Loss Calculated Section 16 Btuh/W	Total Heat Gain Calculated Section 17 Btuh/W
				SUB TOTAL		Section 18	Section 21

SECTION D — BUILDING HEAT LOSS SUMMARY

Building Sub Total Heat Loss (Section 18) ________ Btuh/W

Central Forced Air Ventilation Heat Loss (Section 19) ________ Btuh/W *Only applicable for ventilation case #3

Total Building Heat Loss (Section 20) ________ Btuh/W

SECTION E — BUILDING HEAT GAIN SUMMARY

Building Sub Total Heat Gain (Section 21) ________ Btuh/W

Central Forced Air Ventilation Heat Gain (Section 22) ________ Btuh/W *Only applicable for ventilation case #3

Total Building Heat Gain (Section 23) ________ Btuh/W

Notes:

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HRAI Residential Heat Loss and Heat Gain Calculations						Page 3 of ___		
		HL ΔT = 76		HG ΔT =				
COMPONENTS	STRUCTURE	EFFECTIVE R-VALUE Col 1	$\frac{HL\Delta T}{R}$ Col 2	SC Col 3	$\frac{(HG\Delta T+SC)}{R}$ Col 4	P_E / H / A_F / Area	LVL / RM / HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS								
2.WINDOWS, GLASS DOORS AND SKYLIGHT	NE				THGM			
	N	1.14			THGM			
	SW				THGM			
					THGM			
					THGM			
					THGM			
3.EXPOSED DOORS		6.81						
4.NET EXPOSED WALLS								
5.HEADER AREAS								
6.EXPOSED CEILINGS								
7.EXPOSED FLOORS								
8.OTHER								

9.FOUNDATION CONDUCTIVE HEAT LOSS	☐ BASEMENT ☐ SLAB ON GRADE							
		LVL 1	LVL 2	LVL 3	LVL 4			
10. TOTAL CONDUCTIVE	TOTAL HEAT LOSS							
	TOTAL HEAT GAIN							
11. AIR LEAKAGE	HEAT LOSS MULTIPLIER							
	HEAT GAIN MULTIPLIER							
12a. VENTILATION: EXHAUST ONLY	HEAT LOSS MULTIPLIER							
	HEAT GAIN MULTIPLIER							
12b. VENTILATION: DIRECT DUCTED SYSTEM	HEAT LOSS MULTIPLIER					Qvr		
	HEAT GAIN MULTIPLIER							
13. INTERNAL HEAT GAIN (PEOPLE, LIGHTS, APPLIANCES, PLUG LOADS)								
14. NET LOADS	ADD SECTIONS (10 + 11 + 12 + 13)							
15. DUCT / PIPE HEAT LOSS/GAIN THROUGH UNCONDITIONED SPACES						LOSS		
						GAIN		
16. TOTAL HEAT LOSS FOR EACH ROOM	ADD SECTIONS (14 + 15)					LOSS		
17. TOTAL HEAT GAIN FOR EACH ROOM	ADD SECTIONS (14 + 15) × 1.3					GAIN		
18. SUB TOTAL HEAT LOSS (SUM OF SECTION 16)			20. TOTAL HEAT LOSS ADD SECTIONS (18 + 19)					
19. CENTRAL FORCED AIR VENTILATION HEAT LOSS								
21. SUB TOTAL HEAT GAIN (SUM OF SECTION 17)			23. TOTAL HEAT GAIN ADD SECTIONS (21 + 22)					
22. CENTRAL FORCED AIR VENTILATION HEAT GAIN								

HRAI Residential Heat Loss and Heat Gain Calculations										Page ___ of ___
COMPONENTS	STRUCTURE	P_E / H / A_F	LVL / RM		P_E / H / A_F	LVL / RM		P_E / H / A_F	LVL / RM	
		Area	HEAT LOSS	HEAT GAIN	Area	HEAT LOSS	HEAT GAIN	Area	HEAT LOSS	HEAT GAIN
1.GROSS EXPOSED WALLS										
2.WINDOWS, GLASS DOORS AND SKYLIGHT										
3.EXPOSED DOORS										
4.NET EXPOSED WALLS										
5.HEADER AREAS										
6.EXPOSED CEILINGS										
7.EXPOSED FLOORS										
8.OTHER										
9.FOUNDATION HL										
10. TOTAL CONDUCTIVE										
11. AIR LEAKAGE										
12a. VENTILATION: EXHAUST ONLY										
12b. VENTILATION: DIRECT DUCTED SYSTEM		Qvr			Qvr			Qvr		
13. INTERNAL HEAT GAIN										
14. NET LOADS										
15. DUCT / PIPE HEAT LOSS / GAIN		LOSS			LOSS			LOSS		
		GAIN			GAIN			GAIN		
16. TOTAL HL (ROOM)		LOSS			LOSS			LOSS		
17. TOTAL HG (ROOM)		GAIN			GAIN			GAIN		

HRAI Residential Heat Loss and Heat Gain Calculations Formula Sheet (For Air Leakage / Ventilation Calculation)	Page ___ of ___

BUILDING AIR LEAKAGE HEAT LOSS	BUILDING AIR LEAKAGE HEAT GAIN
$HL_{leak} = B \times LR_{airh} \times Vb \times HL\Delta T$ — B (M) = 0.33, B (I) = 0.018	$HG_{leak} = B \times LR_{airc} \times Vb \times HG\Delta T$ — B (M) = 0.33, B (I) = 0.018
= ___ x ___ x ___ x ___ = [ ]	= ___ x ___ x ___ x ___ = [ ]

AIR LEAKAGE HEAT LOSS/GAIN MULTIPLIER TABLE (SECTION 11)

Level	Level Factor (LF)	Building Air Leakage Heat Loss (HL_{leak})	Level Conductive Heat Loss: see Section 10 (HL_{clevel})	Air Leakage Heat Loss Multiplier ($LF \times HL_{leak} \div HL_{clevel}$)
1				
2				
3				
4				

$$\text{Air Leakage Heat Gain Multiplier} = \frac{HG_{leak}}{\text{Building Conductive Heat Gain}} = \frac{\quad}{\quad} = \boxed{\quad}$$

VENTILATION HEAT LOSS	VENTILATION HEAT GAIN
$HL_{bvent} = C \times PVC \times HL\Delta T \times (1 - E)$ — C (M) = 1.2, C (I) = 1.08	$HG_{bvent} = C \times PVC \times HG\Delta T \times (1 - ATRE)$ — C (M) = 1.2, C (I) = 1.08
= ___ x ___ x ___ x ___ = [ ]	= ___ x ___ x ___ x ___ = [ ]

Case #1: Exhaust Only System (Section 12a) — Heat Loss

Multiplier = Level Factor x HL_{bvent} ÷ Level Cond. Heat Loss

Level	LF	HL_{bvent}	LVL Cond. HL	Multiplier
1				
2				
3				
4				

HL_{rvent} = Multiplier x Room Conductive Heat Loss

Case #1: Exhaust Only System (Section 12a) — Heat Gain

$$\text{Multiplier} = \frac{HG_{bvent}}{\text{Building Conductive Heat Gain}}$$

$$\text{Multiplier} = \frac{\quad}{\quad} = \boxed{\quad}$$

HG_{rvent} = Multiplier x Room Conductive Heat Gain

Case #2: Direct Ducted System (Section 12b) — Heat Loss

Multiplier = C x $HL\Delta T$ x (1 - E) — C (M) = 1.2, C (I) = 1.08

Multiplier = ___ x ___ x ___ = [ ]

Q_{vr} = Room Ventilation Rate
HL_{rvent} = Multiplier x Q_{vr}

Case #2: Direct Ducted System (Section 12b) — Heat Gain

Multiplier = C x $HG\Delta T$ x (1 - ATRE) — C (M) = 1.2, C (I) = 1.08

Multiplier = ___ x ___ x ___ = [ ]

Q_{vr} = Room Ventilation Rate
HG_{rvent} = Multiplier x Q_{vr}

Case #3: Central Forced Air System (Section 19)

Enter HL_{bvent} in Section 19

Case #3: Central Forced Air System (Section 22)

HG_{bvent} x 1.3 = [ ] x 1.3 = [ ]
(enter in Section 22)

HRAI Residential Heat Loss and Heat Gain Calculations Formula Sheet (For Air Leakage / Ventilation Calculation)	Page ____ of ____

BUILDING AIR LEAKAGE HEAT LOSS

B (M) = 0.33
B (I) = 0.018

HL_{leak} = B x LR_{airh} x Vb x HLΔT

= _____ x _____ x _____ x _____ = [ ]

BUILDING AIR LEAKAGE HEAT GAIN

B (M) = 0.33
B (I) = 0.018

HG_{leak} = B x LR_{airc} x Vb x HGΔT

= _____ x _____ x _____ x _____ = [ ]

AIR LEAKAGE HEAT LOSS/GAIN MULTIPLIER TABLE (SECTION 11)

Level	Level Factor (LF)	Building Air Leakage Heat Loss (HL_{leak})	Level Conductive Heat Loss: see Section 10 (HL_{clevel})	Air Leakage Heat Loss Multiplier (LF x HL_{leak} ÷ HL_{clevel})
1				
2				
3				
4				

Air Leakage Heat Gain Multiplier = $\frac{HG_{leak}}{\text{Building Conductive Heat Gain}}$ = ________ = [ ]

VENTILATION HEAT LOSS

C (M) = 1.2
C (I) = 1.08

HL_{bvent} = C x PVC x HLΔT x (1 - E)

= _____ x _____ x _____ x _____ = [ ]

VENTILATION HEAT GAIN

C (M) = 1.2
C (I) = 1.08

HG_{bvent} = C x PVC x HGΔT x (1 - ATRE)

= _____ x _____ x _____ x _____ = [ ]

Case #1: Exhaust Only System (Section 12a) — Heat Loss

Multiplier = Level Factor x HL_{bvent} ÷ Level Cond. Heat Loss

Level	LF	HL_{bvent}	LVL Cond. HL	Multiplier
1				
2				
3				
4				

HL_{rvent} = Multiplier x Room Conductive Heat Loss

Case #1: Exhaust Only System (Section 12a) — Heat Gain

Multiplier = $\frac{HG_{bvent}}{\text{Building Conductive Heat Gain}}$

Multiplier = ________ = [ ]

HG_{rvent} = Multiplier x Room Conductive Heat Gain

Case #2: Direct Ducted System (Section 12b) — Heat Loss

C (M) = 1.2
C (I) = 1.08

Multiplier = C x HLΔT x (1 - E)

Multiplier = _____ x _____ x _____ = [ ]

Q_{vr} = Room Ventilation Rate
HL_{rvent} = Multiplier x Q_{vr}

Case #2: Direct Ducted System (Section 12b) — Heat Gain

C (M) = 1.2
C (I) = 1.08

Multiplier = C x HGΔT x (1 - ATRE)

Multiplier = _____ x _____ x _____ = [ ]

Q_{vr} = Room Ventilation Rate
HG_{rvent} = Multiplier x Q_{vr}

Case #3: Central Forced Air System (Section 19)

Enter HL_{bvent} in Section 19

Case #3: Central Forced Air System (Section 22)

HG_{bvent} x 1.3 = [ ] x 1.3 = [ ]
(enter in Section 22)

HRAI WINDOW SHADING WORKSHEET

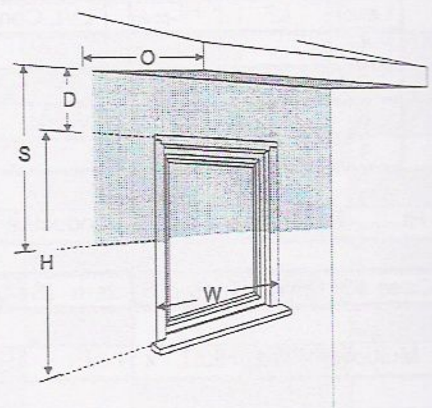
Page ____ of ____

Latitude = ____ °

Level							
Room Name							
Direction Window Faces							
W (ft / m) Width of Window							
H (ft / m) Height of Window							
A (ft² / m²) Total Window Area							
O (ft / m) Width of Overhang							
F (see Table below) F-Shade Factor							
S (ft / m) S = F x O Shade Line							
D (ft / m) Drop							
SA (ft² / m²) SA = (S-D) x W Shaded Area							
UA (ft² / m²) UA = A - SA Unshaded Area							

NOTES:

1. Shaded area SA will be marked on the HRAI Worksheets as "north"
2. Unshaded area (UA) will be marked on the HRAI Worksheets as the direction the window actually faces
3. Shading calculations are not required for north, northeast and northwest facing windows.
4. If the shaded area (SA) is greater than the window area (A), then: SA = A Shaded area (SA) is never more than window area (A)
5. If shaded area (SA) is negative use a value of zero.



F Shade Factor

Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

TRANSPARENT ASSEMBLY HEAT GAIN MULTIPLIER (THGM) WORKSHEET

Page ____ of ____

Transparent Assembly Heat Gain Multiplier (THGM)

$$THGM = \frac{HG\Delta T}{R} + (SHGC \times SOLAR \times ISF)$$

THGM Calculation Table							
		Facing Direction					
		North & Shaded	South	East / West	Northeast / Northwest	Southeast / Southwest	Horizontal
North Latitude		°					
HG∆T		°F / °C					
Effective R-value							
#1	$\frac{HG\Delta T}{R}$						
#2	SHGC						
#3	SOLAR						
#4	ISF						
#5	(#2) × (#3) × (#4)						
#6	THGM=(#1) + (#5)						

SOLAR = Estimated Solar Radiation												
Latitude	North & Shaded		South		East / West		Northeast / Northwest		Southeast / Southwest		Horizontal	
	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²	Imperial Btu/h/ft²	Metric W/m²
40	29	93	51	160	90	285	62	194	80	252	169	534
41	29	93	53	166	90	285	62	194	83	261	169	534
42	29	93	55	172	90	285	62	194	86	271	169	534
43	29	93	56	178	90	285	62	194	89	280	169	534
44	29	93	58	184	90	285	62	194	92	290	169	534
45	29	93	60	190	90	285	62	194	95	299	169	534
46	29	93	62	196	90	285	62	194	98	309	169	534
47	29	93	64	202	90	285	62	194	101	318	169	534
48 to 82	29	93	66	208	90	285	62	194	104	328	169	534

ISF = Internal Shading Factors				
Type of interior shading	Type of glazing systems			
	Single	Double	Triple	Heat Mirror
No interior shades	1	1	1	1
Interior blinds, curtains, and etc.	0.50	0.55	0.57	0.60
Interior reflective metallic blinds or screens	0.35	0.37	0.40	0.44

APPENDIX A

R VALUES AND HEAT GAIN FACTORS

IMPERIAL UNITS

INSTRUCTIONS FOR CALCULATING ASSEMBLY R VALUES

Tables 1 and Appendix B can be used to determine the assembly or effective R values for most wood framed wall, floor and ceiling assemblies.

Table 1 lists the combined R-values of the cavity insulation and wood framing only and the values are based on the Isothermal Planes method described in Section 9.36 of the National Building Code and the ASHRAE Book of Fundamentals. The R-values that are listed in Table 1 are developed under the assumption of solid lumber framing with 16" (406 mm) centres; 23% framing, 77% insulation. Designers may choose to use the detailed calculations shown in Appendix C if they want more precise results.

R values for assemblies with no framing (Insulated Concrete Forms (ICFs) or Structural Insulated Panels (SIPs) need to be determined based on the detailed calculations in Appendix C. Floors and ceilings framed with engineered joists or open web joists will have slightly higher R values than determined from these Tables due to reduced framing losses and may also be determined based on Appendix C for increased precision

Step 1) Determine the nominal (insulation only) R value of the cavity insulation of the building assembly using the provided drawings, insulation specifications such as CCMC (Canadian Construction Materials Centre) reports, R values in Appendix B based on the thickness of the insulation.

- The thickness of the insulation is equal to the depth of the framing members for the assembly **only** if the cavity is full of insulation
- For ceilings with attic spaces where the insulation exceeds the depth of the bottom cord of the truss or framing material, use the depth of the framing material for **Step 1** and use the balance of the insulation in **Step 3**.

Step 2) Look up the Effective R value of the Assembly in Table 1 based on the Nominal R Value found in **Step 1** and the Framing Depth.

- R values below the solid line are not included since they are impossible to achieve using conventional insulation materials (greater than 0.0485 RSI/mm = 7 R/in) based on the depth of the framing material.
- Batt insulation with nominal R values based on an uncompressed thickness that is greater than the framing depth should not be used. Use Appendix B R values based on the framing depth.
- Use the 2x12 column for Headers.

Step 3) Add the R value of any continuous layers(e.g. exterior siding, continuous insulation without farming, sheathing, drywall and inside/outside air films) to the result of **Step 2** using the R values from the provided drawings, insulation specifications such as CCMC reports, Values in Appendix B.

INSTRUCTIONS FOR CALCULATING ASSEMBLY R VALUES

Tables 1 and Appendix B can be used to determine the assembly or effective R values for most wood framed wall, floor and ceiling assemblies.

Table 1 lists the combined R-values of the cavity insulation and wood framing only and the values are based on the Isothermal Planes method described in Section 9.36 of the National Building Code and the ASHRAE Book of Fundamentals. The R-values that are listed in Table 1 are developed under the assumption of solid lumber framing with 16" (406 mm) centres; 23% framing, 77% insulation. Designers may choose to use the detailed calculations shown in Appendix C if they want more precise results.

R values for assemblies with no framing (Insulated Concrete Forms (ICFs) or Structural Insulated Panels (SIPs) need to be determined based on the detailed calculations in Appendix C. Floors and ceilings framed with engineered joists or open web joists will have slightly higher R values than determined from these Tables due to reduced framing losses and may also be determined based on Appendix C for increased precision

Step 1) Determine the nominal (insulation only) R value of the cavity insulation of the building assembly using the provided drawings, insulation specifications such as CCMC (Canadian Construction Materials Centre) reports, R values in Appendix B based on the thickness of the insulation.

- The thickness of the insulation is equal to the depth of the framing members for the assembly **only** if the cavity is full of insulation
- For ceilings with attic spaces where the insulation exceeds the depth of the bottom cord of the truss or framing material, use the depth of the framing material for **Step 1** and use the balance of the insulation in **Step 3**.

Step 2) Look up the Effective R value of the Assembly in Table 1 based on the Nominal R Value found in **Step 1** and the Framing Depth.

- R values below the solid line are not included since they are impossible to achieve using conventional insulation materials (greater than 0.0485 RSI/mm = 7 R/in) based on the depth of the framing material.
- Batt insulation with nominal R values based on an uncompressed thickness that is greater than the framing depth should not be used. Use Appendix B R values based on the framing depth.
- Use the 2x12 column for Headers.

Step 3) Add the R value of any continuous layers(e.g. exterior siding, continuous insulation without farming, sheathing, drywall and inside/outside air films) to the result of **Step 2** using the R values from the provided drawings, insulation specifications such as CCMC reports, Values in Appendix B.

Table 1: Effective R Value for Wood Framed Assemblies (based on 16" centres with 23% Framing)

Nominal R Value	Framing Size: 2x2,1x2 or 1x4 strapping	2x4	2x6	2x8	2x10	2x12 or Headers
Uninsulated Air Cavity	1.14	1.24	1.27	1.28	1.29	1.30
2	1.96	2.28	2.39	2.44	2.47	2.49
4	3.15	4.07	4.42	4.60	4.71	4.79
6	3.95	5.50	6.16	6.52	6.76	6.92
8	4.53	6.68	7.68	8.25	8.63	8.89
10	4.96	7.67	9.01	9.81	10.34	10.72
12		8.50	10.19	11.22	11.93	12.43
14		9.22	11.24	12.51	13.39	14.03
16		9.85	12.18	13.69	14.75	15.53
18		10.39	13.02	14.77	16.01	16.94
20		10.88	13.79	15.76	17.19	18.26
22		11.31	14.49	16.69	18.29	19.51
24		11.69	15.13	17.54	19.32	20.69
26			15.72	18.33	20.28	21.80
28			16.26	19.07	21.19	22.85
30			16.76	19.76	22.05	23.85
32			17.22	20.41	22.86	24.80
34			17.65	21.02	23.62	25.70
36			18.05	21.59	24.35	26.56
38			18.43	22.13	25.03	27.38
40				22.63	25.68	28.16
42				23.11	26.30	28.91
44				23.57	26.89	29.62
46				24.00	27.46	30.30
48				24.41	27.99	30.96
50				24.79	28.50	31.59
52				25.16	28.99	32.19
54					29.46	32.77
56					29.91	33.32
58					30.34	33.86
60					30.75	34.37

Summary: The effective R Value of the assembly is:

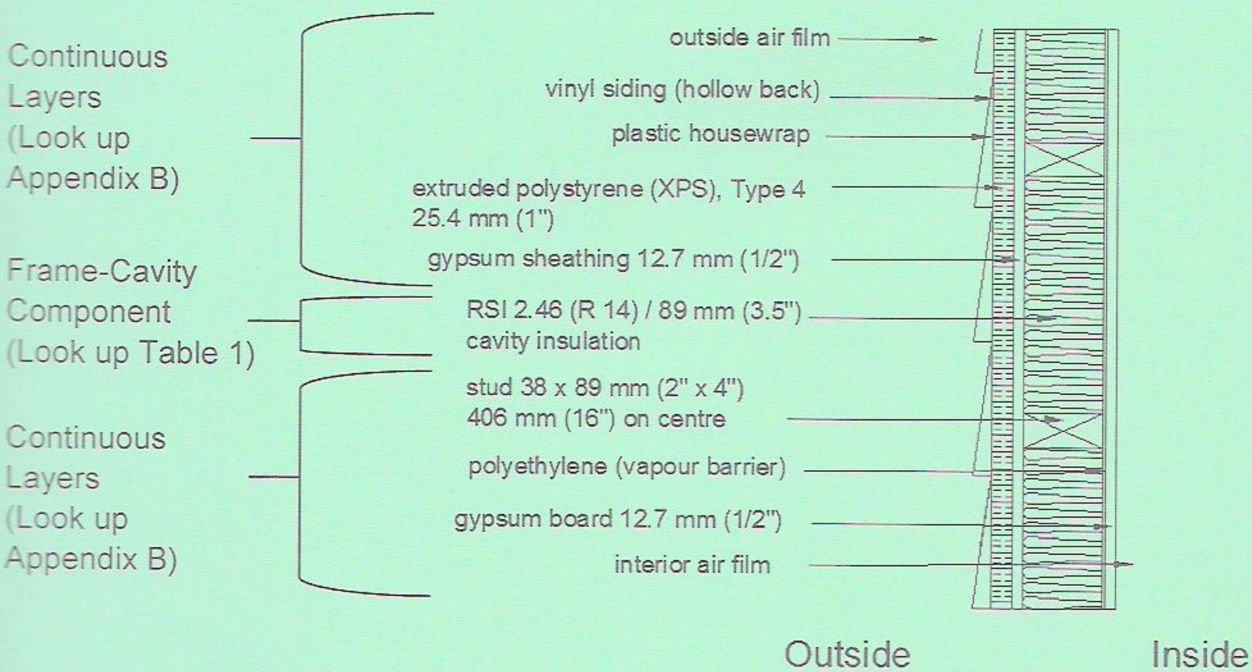
Effective R Value of the cavity and framed assembly only
+
Nominal R Value of Continuous Layers

OR

Step 2 (Table 1)
+
Step 3 (Appendix B)

Students are encouraged to use the following R-value calculation worksheet provided below. A sample calculation is also provided.

Sample Calculation: R-value Calculation of Wood Framed Wall



Sample Calculation: R-value Calculation of Wood Framed Wall (Cont'd)

Structure	Wood Framed Wall	
Layer	R-Value	Reference
Outside air film - walls	0.17	App. B, B-2
Vinyl siding – hollow backed	0.62	App. B, B-2
Plastic Housewrap	-	-
1" extruded polystyrene (Type 4)	5.05	App. B, B-3
1/2 " gypsum sheathing	0.46	App. B, B-4
Frame-Cavity: 2" x 4" wood stud, 16" o.c. filled with R14 batt	9.22	Table 1
Polyethylene vapour barrier	-	-
1/2" gypsum board (interior finish)	0.44	App. B, B-5
Inside air film	0.68	App. B, B-2
TOTAL EFFECTIVE R-VALUE	16.64	

Note: R-values for polyethylene vapour barrier and housewrap are considered to be negligible.

R-VALUE CALCULATION WORKSHEET

Structure

Layer	R-Value	Reference
TOTAL EFFECTIVE R-VALUE		

Structure

Layer	R-Value	Reference
TOTAL EFFECTIVE R-VALUE		

WINDOWS, SKYLIGHTS, SLIDING GLASS DOORS AND GLAZED PORTIONS OF DOORS

Table 2: R value and SHGC of single glazed windows

Frame Material	Storm	R value h·ft²·°F/Btu	SHGC
Fixed - Aluminum	No	0.85	0.73
	Yes	1.31	0.65
Fixed - Wood	No	1.08	0.67
	Yes	1.87	0.60
Operable - Aluminum	No	0.74	0.71
	Yes	1.14	0.63
Operable - Wood	No	1.19	0.55
	Yes	1.87	0.49

Note: There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative R values and SHGC.

Table 3: R value and SHGC of double glazed windows

Frame Material	Spacer	Coatings	Glazing spacing									
			1/4"				11/32"		1/2"			
			Air		Argon		Krypton		Air		Argon	
			R value	SHGC	R value	SHGC	R value	SHGC	R value	SHGC	R value	SHGC
Fixed - Aluminum	Metal	Clear	1.25	0.65	1.25	0.65	1.36	0.65	1.31	0.65	1.36	0.65
		Low-E	1.42	0.47	1.53	0.47	1.76	0.47	1.59	0.47	1.70	0.47
	Insulating	Clear	1.25	0.65	1.31	0.65	1.42	0.65	1.36	0.65	1.42	0.65
		Low-E	1.48	0.47	1.65	0.47	1.87	0.47	1.70	0.47	1.82	0.47
Fixed - Wood/Vinyl	Metal	Clear	1.70	0.60	1.82	0.60	1.99	0.60	1.87	0.60	1.99	0.60
		Low-E	2.04	0.47	2.33	0.47	2.90	0.47	2.56	0.47	2.56	0.47
	Insulating	Clear	1.82	0.59	1.99	0.59	2.16	0.59	2.04	0.59	2.16	0.59
		Low-E	2.27	0.47	2.67	0.47	3.35	0.47	2.90	0.47	3.24	0.47
Operable - Aluminum	Metal	Clear	1.08	0.63	1.08	0.63	1.14	0.63	1.14	0.63	1.14	0.63
		Low-E	1.19	0.47	1.25	0.47	1.87	0.47	1.31	0.47	1.36	0.47
	Insulating	Clear	1.08	0.63	1.14	0.63	1.19	0.63	1.14	0.63	1.19	0.63
		Low-E	1.19	0.47	1.65	0.47	1.48	0.47	1.36	0.47	1.48	0.47
Operable - Wood/Vinyl	Metal	Clear	2.10	0.49	1.82	0.49	1.99	0.49	1.87	0.49	1.93	0.49
		Low-E	2.33	0.47	2.21	0.47	2.61	0.47	2.38	0.47	2.56	0.47
	Insulating	Clear	2.33	0.49	1.99	0.49	2.16	0.49	2.04	0.49	2.10	0.49
		Low-E	2.61	0.47	2.50	0.47	2.95	0.47	2.67	0.47	2.90	0.47

Note:

1) Rough openings for windows shall be used in the calculations.

2) If space between adjacent panes is less than 6 mm, glazing shall be treated as one layer.

3) There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative R values and SHGC

Table 4: R value and SHGC of triple glazed windows with one coating

Frame Material	Spacer	Coatings	Glazing spacing									
			1/4"				11/32"		1/2"			
			Air		Argon		Krypton		Air		Argon	
			R value	SHGC	R value	SHGC	R value	SHGC	R value	SHGC	R value	SHGC
Fixed - Aluminum	Metal	Clear	1.48	0.58	1.53	0.58	1.65	0.58	1.59	0.58	1.65	0.58
		Low-E	1.59	0.40	1.70	0.40	1.93	0.40	1.82	0.40	1.93	0.40
	Insulating	Clear	1.53	0.58	1.59	0.58	1.76	0.58	1.70	0.58	1.76	0.58
		Low-E	1.70	0.40	1.82	0.40	2.10	0.40	1.93	0.40	2.04	0.40
Fixed - Wood/Vinyl	Metal	Clear	2.21	0.53	2.33	0.53	2.67	0.53	2.50	0.53	2.61	0.53
		Low-E	2.44	0.40	2.78	0.40	3.41	0.40	3.07	0.40	3.35	0.40
	Insulating	Clear	2.44	0.53	2.67	0.53	3.12	0.53	2.95	0.53	3.07	0.53
		Low-E	2.84	0.40	3.24	0.40	4.26	0.40	3.75	0.40	4.14	0.40
Operable - Aluminum	Metal	Clear	1.19	0.57	1.25	0.57	1.36	0.57	1.31	0.57	1.31	0.57
		Low-E	1.31	0.40	1.36	0.40	1.53	0.40	1.42	0.40	1.48	0.40
	Insulating	Clear	1.53	0.58	1.31	0.57	1.42	0.57	1.36	0.57	1.42	0.57
		Low-E	1.70	0.40	1.82	0.40	1.59	0.40	1.53	0.40	1.59	0.40
Operable - Wood/Vinyl	Metal	Clear	2.10	0.44	2.21	0.44	2.50	0.44	2.38	0.44	2.50	0.44
		Low-E	2.33	0.40	2.50	0.40	3.01	0.40	2.78	0.40	2.95	0.40
	Insulating	Clear	2.33	0.44	2.50	0.44	2.95	0.43	2.84	0.43	2.95	0.43
		Low-E	2.61	0.40	2.90	0.40	3.75	0.40	3.41	0.40	3.63	0.40

Note:

1) Rough openings for windows shall be used in the calculations.

2) If space between adjacent panes is less than 6 mm, glazing shall be treated as one layer.

3) There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative R values and SHGC

Table 5: R value and SHGC of triple glazed windows with two coatings

Frame Material	Spacer	Coatings	Glazing spacing									
			1/4"				11/32"		1/2"			
			Air		Argon		Krypton		Air		Argon	
			R value	SHGC	R value	SHGC	R value	SHGC	R value	SHGC	R value	SHGC
Fixed - Aluminum	Metal	Low-E	1.70	0.25	1.82	0.25	2.10	0.25	1.93	0.25	2.04	0.25
	Insulating	Low-E	1.82	0.25	1.99	0.25	2.27	0.25	2.10	0.25	2.21	0.25
Fixed - Wood/Vinyl	Metal	Low-E	2.73	0.22	3.07	0.22	3.92	0.22	3.46	0.22	3.80	0.22
	Insulating	Low-E	3.12	0.22	3.63	0.22	5.05	0.22	4.32	0.22	4.88	0.22
Operable - Aluminum	Metal	Low-E	1.36	0.26	1.42	0.26	1.59	0.26	1.53	0.26	1.59	0.26
	Insulating	Low-E	1.42	0.26	1.53	0.26	1.70	0.26	1.59	0.26	1.65	0.26
Operable - Wood/Vinyl	Metal	Low-E	2.50	0.19	2.73	0.19	3.29	0.19	3.01	0.19	3.24	0.19
	Insulating	Low-E	2.84	0.19	3.12	0.19	4.20	0.19	3.75	0.19	4.09	0.19

Note:

1) Rough openings for windows shall be used in the calculations.
2) If space between adjacent panes is less than 1/4", glazing shall be treated as one layer.
3) There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative R values and SHGC

Table 6: R value for doors

Doors	Thermal resistance	
	Without storm door	With storm door
Solid wood 1 3/4" thick	3.01	4.03
Panel type wood 1 1/4" thick	2.56	3.58
Insulated metal - Polystyrene core	5.68	6.81
Insulated metal - Polyurethane core	6.25	7.38
Insulated fiberglass - Polystyrene core	4.83	5.96
Insulated fiberglass - Polyurethane core	5.68	6.81

Note: Rough openings for doors shall be used in the calculations.

Table 7: Level factors for applying air leakage fractions to room in different levels

Number of levels / Level	One (e.g. slab on grade bungalow)	Two (e.g. bungalow with basement, two-storey slab on grade)	Three (e.g. two-storey house on basement)	Four (e.g. three-storey house on basement)
Lowest Level	1.0	0.6	0.5	0.4
2nd level up		0.4	0.3	0.3
3rd level up			0.2	0.2
4th level up				0.1

Table 8: DUCT MULTIPLIERS

DUCT MULTIPLIERS			
DUCT LOCATION	R-Value of DUCT INSULATION VALUE	DUCT LOSS MULTIPLIER	DUCT GAIN MULTIPLIER
attic or open crawlspace	NONE 3.97 7.95 11.92 19.87 or greater	0.25 0.15 0.10 0.05 -----	0.25 0.15 0.10 0.05 -----
unconditioned basement	11.92	-----	0.05
enclosed, unconditioned crawlspace	NONE 3.97 7.95 19.87 19.87 or greater	0.25 0.15 0.10 0.05 -----	0.25 0.15 0.10 0.05 ------
slab-on-grade with perimeter insulation	All values	0.10	-----

Note: this table provides adjustment multipliers for heat loss and heat gain calculations for when ducts serving the building or rooms pass through or are located in unconditioned space.

Table 9: PIPE LOSS MULTIPLIERS

PIPE LOSS MULTIPLIERS			
Pipe Heat Flux [BTU/h/ft2]	TYPE OF CIRCULATION	INSULATED PIPE	UNINSULATED PIPE
31.7 BTU/h/ft2 or less	Gravity Pumped	0.2 0.1	1.0 0.6
Greater than 31.7 BTU/h/ft2	Gravity Pumped	0.1 0.0	0.5 0.3

Table 10: Solar corrections for heat gain calculations – normal procedure

Building Assembly	Solar correction, SC (°F), by Summer Mean Daily Temperature Range	
	Up to and including 25°F	Over 25°F
Walls, headers, and doors	0	-6
Interior partitions and fully shaded exterior walls, headers and doors	-6	-11
Roofs and top storey ceilings	+27	+22
Floors over non-conditioned rooms and ceilings under non-conditioned rooms	-6	-11

Table 11: Solar corrections for heat gain calculations – detailed procedure

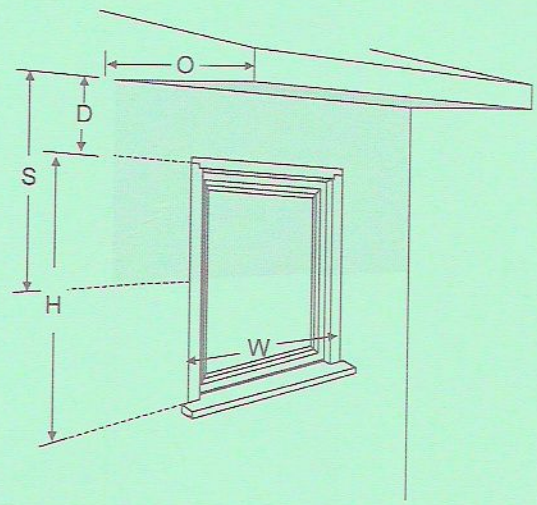
Building Assembly	Orientation	Solar correction, SC (°F), by Summer Mean Daily Temperature Range	
		Up to and including 25 °F	Over 25 °F
Walls, headers and doors	Factor for whole house calculation	0	-6
	North	-7	-12
	Northeast and Northwest	-1	-6
	East and West	+3	-2
	Southeast and Southwest	+1	-4
	South	-4	-9
Interior partitions and fully shaded exterior walls, headers and doors		-6	-11
Roofs and top storey ceilings		+27	+22
Floors over non-conditioned rooms and ceilings under non-conditioned rooms		-6	-11

Note: This chart is only to be used if solar correction is required to be calculated by wall orientation such as when calculating heat gain for row housing or condominiums with exposed walls facing in only 1 or 2 directions. The normal procedure is to use the simplified "Solar corrections for heat gain calculations – normal procedure" chart found at top of this page

CALCULATING SHADED AND UNSHADED AREAS OF WINDOWS

To calculate a window area that is shaded, both the shaded and unshaded areas must be determined.

The following formulas are used to determine the areas:



i) S = F x O

where: S = Distance to Shade Line
F = Shade Factor (from table below)
O = Width of Overhang (measured)

ii) SHADED AREA = (S - D) x W

where: W= Width of Window (measured)
S = Distance to Shade Line
D = Head Drop (measured)

Note: SHADED AREA cannot exceed H x W

iii) UNSHADED AREA = H x W - (SHADED AREA)

Where: H = Window Height (measured)
W = Window Width (measured)

Note: If D is greater than S, then SHADED AREA = 0

Special Note

This manual requires that H and W be measured from the rough frame opening. This allows the window dimensions from the heat loss calculations to also be used in the heat gain calculation.

The following SHADE FACTORS are used regardless of the units in which the calculation is being done.

Table 12: External F-Shade Factors

F Shade Factor							
Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

Table13: Estimated solar radiation (BTU/h/ft2)

North Latitude (°)	North & Shaded Windows	South	East/ West	Northeast/ Northwest	Southeast/ Southwest	Horizontal
40	29	51	90	62	80	169
41	29	53	90	62	83	169
42	29	55	90	62	86	169
43	29	56	90	62	89	169
44	29	58	90	62	92	169
45	29	60	90	62	95	169
46	29	62	90	62	98	169
47	29	64	90	62	101	169
48 to 82	29	66	90	62	104	169

Table 14: Internal shading factors

Type of interior shading	Type of glazing systems			
	Single	Double	Triple	Heat mirror
No interior shades	1	1	1	1
Interior blinds, curtains...etc.	0.50	0.55	0.57	0.60
Interior reflective metallic blinds or screens	0.35	0.37	0.40	0.44
Exterior roll shutters and screen shadings	see Notes (1) and (2)	see Notes (1) and (2)	see Notes (1) and (2)	see Notes (1) and (2)

1) Between-pane reflective metallic blinds, and exterior shutters and screen shadings could generally be treated as walls with respect to solar gain, since the amount of solar transmitted is a small part of the load. In that case, the insulation value of the shade should only be added to the insulation value of the external shutter or shade (if they are fully closed).

2) For exterior shutters and screen shadings, use manufacturer's data when available. To account for both solar and conductive gains, refer to "Guidelines for Effective Residential Solar Shading Devices", Laouadi, A., National Research Council of Canada, March 2010, IRC-RR-300.

Table 15: Principal Ventilation Capacity (PVC)

Table 15a
National Building Code
Table 9.32.3.3
Normal Operating Exhaust Capacity of Principal Ventilation Fan

Number of bedrooms	Capacity			
	Minimum		Maximum	
	CFM	L/s	CFM	L/s
1	34	16	**51**	**24**
2	38	18	**59**	**28**
3	47	22	**68**	**32**
4	55	26	**81**	**38**
5	64	30	**95**	**45**
More than 5 bedrooms and the system must comply to CSA- F326				

Note: As seen above National building code lists both minimum and maximum requirement for Principal Ventilation Capacity. For ventilation heat loss and heat gain calculation use the maximum PVC.

Table 15b
Ontario Building Code
Table 9.32.3.4.A

Principal Exhaust Fan Capacity

Number of Bedrooms	Capacity	
	CFM	L/s
1	30	15
2	45	22.5
3	60	30
4	75	37.5
5	90	45
More than 5	Part 6 design	

Table 15c
British Columbia Building Code
Table 9.32.3.3.A
Principal Exhaust Fan Ventilation Rate (cfm)
Forming part of clause 9.32.3.3.(1)(a)

Floor Area, ft^2	Number of Bedroom*				
	0-1	2-3	4-5	6-7	>7
<1500	30	44	59	74	89
1500-3000	44	59	74	89	104
3001-4500	59	74	89	104	119
4500-6000	74	89	104	119	136
6001-7500	89	104	119	136	150
>7500	104	119	136	150	165

Note*: A bedroom is considered as a room with a window conforming to Article 9.9.10.1 and an interior closing door.

APPENDIX B

SUPPLEMENTARY INFORMATION FOR DETAILED R-VALUE CALCULATIONS

IMPERIAL UNITS

Note(s):

Except where noted, the values listed are taken from the NRCan "Tables for calculating Effective Thermal Resistance of Opaque Assemblies" December 2012 and Table A - 9.36.2.4. (1) D from National building code. Look for NRCan and National Building Code reference for insulation.

This document provides thermal resistance properties of opaque assembly materials required to calculate the total effective thermal resistance of building assemblies under the *2012 ENERGY STAR® for New Homes (ESNH) Standard*. The format is designed to provide simple, easy-to-use look-up tables for the effective thermal resistance of portions of assemblies containing continuous material layers (including air films).

NOTE*:
Values in Italic are taken from CAN/CSA-F280 Standard.

Thermal Resistance Values for Building Materials			
Description		Thermal resistance (R) Per inch (h.ft²•°F/Btu)/in	Thermal resistance (R) As listed (h.ft²•°F/Btu)
Air Films			
Exterior:	ceiling, floors and walls wind 22 ft/s (winter)	-	0.17
Interior:	ceiling (heat flow up)	-	0.62
	floor (heat flow down)	-	0.91
	walls (heat flow horizontal)	-	0.68
Vented Roof Air Space			
Cathedral, flat and attic		-	0.17
Air Cavities			
Air spaces less than or equal to 12 mm, 1/2 inch minimum dimension		-	*negligible*
Ceiling (heat flow up):	0.5 - 0.75 inch air space	-	0.85
	0.75 - 3.5 inch air space	-	0.91
Floors (heat flow down):	0.5 - 0.75 inch air space	-	0.91
	0.75 - 1.5 inch air space	-	1.02
	1.5 - 3.5 inch air space	-	1.14
	3.5 inch air space	-	1.25
Walls (heat flow horizontal):	0.5 - 0.75 inch air space	-	0.91
	0.75 - 3.5 inch air space	-	1.02
Cladding Materials			
Brick:	fired clay (150 lb/ft³)	0.10	-
	concrete: sand and gravel, or stone (150 lb/ft³)	0.058	-
Siding:	Fibre-cement	0.43	-
	Hardboard, 1/2 inch	-	0.68
	Plywood, 0.35 inch -lapped	-	0.57
	Vinyl, hollow-backed	-	0.62
	Vinyl, insulating-board-backed: 0.35 inch nominal	-	1.82
	Wood, 0.5 inch	-	0.79
Metal Siding:	*Horizontal clapboard profile*	-	*0.70*
	Horizontal clapboard profile with backing	-	*1.40*
	Vertical V-groove profile	-	*0.70*
Stone:	Quartzitic and sandstone (140 lb/ft³)	0.04	-
	Calcitic, dolomitic, limestone, marble and granite (140 lb/ft³)	0.06	-
Wood Shingles:	15.5 inch, 7.5 inch exposure	-	0.85
	15.5 inch, 11.8 inch exposure (double exposure)	-	1.19
	insulating backer board	-	1.42
Stucco and mortar, cement/lime		0.13	-
Roofing Materials			
Asphalt roll roofing		-	0.17
Asphalt/tar		0.20	-
Build-up roofing		-	0.34
Crushed stone		0.09	-
Metal deck		-	negligible
Shingle	asphalt	-	0.45
	wood	-	0.97
Slate		-	0.06

Thermal Resistance Values for Building Materials				
Description			Thermal resistance (R) Per inch (h.ft²•°F/Btu)/in	Thermal resistance (R) As listed (h.ft²•°F/Btu)
Insulation Materials				
Blanket and Batt:				
Rock or glass fibre (CAN ULC S702)	R-12 (3.5 inch)		-	12.00
	R-14 (3.5 inch)		-	14.00
	R-19 (R-20 batt compressed) (5.5 inch)		-	19.00
	R-20 (6 inch)		-	20.00
	R-22 (5.5/6 inch)		-	22.00
	R-22.5 (6 inch)		-	22.50
	R-24 (5.5/6 inch)		-	24.00
	R-28 (7/8.5 inch)		-	28.00
	R-31 (9.5 inch)		-	31.00
	R-35 (10.5 incn)		-	35.00
	R-40 (11/12 inch)		-	40.00
Boards and Slabs:				
Polyisocyanurate (PIR) and Polyurethane (PUR) Board CAN/ULC S704)	Permeably faced		5.51	-
	Impermeably faced		5.68	-
Expanded Polystyrene Insulation Board (EPS) (CAN/ULC S701)	Type 1		3.75	-
	Type 2		4.04	-
	Type 3		4.33	-
Extruded Polystyrene Insulation Board (XPS) (CAN/ULC S701)	Types 2, 3& 4		5.05	-
Rock fibre semi-rigid board			3.99	-
Glass fibre semi-rigid board			4.30	-
Roof board			2.60	-
Building board or ceiling tile, lay-in panel			2.31	-
Natural Cork			3.71	-
Phenolic thermal insulation			4.38	-
Spray-Applied:				
Sprayed polyurethane foam, medium density closed cell (CAN/ULC S705.1)			5.19	-
Sprayed polyurethane foam, light density open cell (CAN/ULC S705.1)			3.75	-
Sprayed Cellulosic fi bre (settled thickness)			3.46	-
Spray-applied glass-fibre insulation: 1 lb/ft³ (CAN/ULC S702)			3.61	-
Sprayed Asbestos			2.89	-
Loose-fill insulation:				
Wood shavings			2.44	-
Cellulose (CAN/ULC S703)			3.61	-
Glass fibre loose fill insulation for attics - 4.5 inch to 22 inch (CAN/ULC S702)			2.70	-
Glass fibre loose fill insulation for walls (CAN/ULC S702)			4.13	-
Perlite			2.74	-
Vermiculite			2.16	-

Thermal Resistance Values for Building Materials			
Description		Thermal resistance (R)	
		Per inch (h.ft²•°F/Btu)/in	As listed (h.ft²•°F/Btu)
Sheet Materials			
Gypsum board (sheathing)		0.91	-
Insulating fibreboard (Type 2 sheathing)		2.31	-
Plywood (generic softwood)		1.26	-
Plywood, Douglas-fir		1.60	-
Oriented strand board (OSB)		1.41	-
Particleboard	low density (37 lb/ft³)	1.41	-
	medium density (50 lb/ft³)	1.11	-
	high density (62 lb/ft³)	0.85	-
Sheet Materials	permeable felt	-	0.06
	seal, 2 layers of mopped (0.046 lb/ft³)	-	1.19
	seal, plastic film	-	negligible
Waferboard (44 lb/ft³)		1.37	-
Structural Materials			
Concrete	Sand and gravel or stone aggregate (150 lb/ft³)	0.058	-
	Expanded shale, clay, slate or slag's, cinders (100 lb/ft³)	0.19	-
	Perlite, vermiculite and polystyrene bead (30 lb/ft³)	0.91	-
Hardwood	Ash	0.91	-
	Birch	0.79	-
	Maple	0.91	-
	Oak	0.746	-
SoftWood	Amabilis fir	1.15	-
	California redwood	1.28	-
	Douglas fir-larch	0.99	-
	Eastern white ceder	1.43	-
	Eastern White pine	1.33	-
	Hemlock-fir	1.21	-
	Lodgepole pine	1.18	-
	Red pine	1.11	-
	Western hemlock	1.07	-
	Western red cedar	1.47	-
	White spruce	1.39	-
	Yellow cyprus-cedar	1.11	-
Wood, structural framing, spruce-pine-fir		1.23	-
Steel, galvanized sheet, 0.14% carbon content		0.002	-

Thermal Resistance Values for Building Materials				
Description			Thermal resistance (R)	
			Per inch (h.ft²•°F/Btu)/in	As listed (h.ft²•°F/Btu)
Interior Finish Materials				
Gypsum board (interior finish)			0.88	-
Hardboard- medium density (50 lb/ft³)			1.37	-
Interior finish (plank, tile) board			2.85	-
Flooring material	carpet and fibrous pad		-	2.10
	carpet and rubber pad		-	1.25
	cork tile		-	0.28
	Hardwood flooring		-	0.68
	Terrazzo		-	0.08
	Tile (linoleum,vinyl,rubber)		-	0.05
	Tile (ceramic)		-	0.03
	Wood subfloor		-	0.97
	Wood fibre tiles - 13mm, 1/2 inch		-	*1.19*
Plastering	Cement plaster: sand aggregate		0.20	-
Gypsum plaster	low density aggregate		0.63	-
	sand aggregate		0.17	-
Hollow clay Bricks				
Multi-cored without insulation in cores		3.5 inch	-	1.53
Rectangular 2-core	no insulation in cores	5.5 inch	-	2.21
		7.5 inch	-	2.33
		11.5 inch	-	2.67
	cores filled with vermiculite	5.5 inch	-	3.69
		7.5 inch	-	4.88
		11.5 inch	-	7.32
Rectangular 3-core	no insulation in cores	3.5 inch	-	1.99
		5.5 inch	-	2.16
		7.5 inch	-	2.33
		9.5 inch	-	2.44
		11.5 inch	-	2.56
	cores filled with vermiculite	5.5 inch	-	3.86
		7.5 inch	-	4.88
		9.5 inch	-	6.02
		11.5 inch	-	6.76

Thermal Resistance Values for Building Materials				
Description			Thermal resistance (R)	
			Per inch (h.ft²•°F/Btu)/in	As listed (h.ft²•°F/Btu)
Concrete Blocks				
Limestone aggregate with 2 cores cores filled with perlite		7.5 inch	-	2.10
		11.5 inch	-	3.69
Light Weight units (expanded shale, clay, slate or slag aggregate) with 2 or 3 cores	no insulation in cores	3.5 inch	-	1.36
		5.5 inch	-	1.70
		7.5 inch	-	1.82
		9.5 inch	-	1.87
		11.5 inch	-	2.33
	cores filled with perlite	5.5 inch	-	4.20
		7.5 inch	-	5.62
		11.5 inch	-	7.67
	cores filled with vermiculite	5.5 inch	-	3.29
		7.5 inch	-	4.60
		9.5 inch	-	5.56
		11.5 inch	-	6.02
	cores filled with molded EPS beads	7.5 inch	-	4.83
	molded EPS inserts in cores	7.5 inch	-	3.52
Medium weight units (combination of normal and low mass aggregate) with 2 or 3 cores.	no insulation in cores	7.5 inch	-	1.48
	cores filled with molded EPS beads		-	3.18
	molded EPS inserts in cores		-	2.67
	cores filled with perlite		-	3.01
	cores filled with vermiculite		-	3.29
Normal weight units (sand and gravel aggregate) with 2 or 3 cores	no insulation in cores	3.5 inch	-	0.97
		5.5 inch	-	1.08
		7.5 inch	-	1.19
		9.5 inch	-	1.36
		11.5 inch	-	1.48
	cores filled with perlite	7.5 inch	-	1.99
	cores filled with vermiculite	5.5 inch	-	2.27
		7.5 inch	-	2.90
		9.5 inch	-	3.46
		11.5 inch	-	3.92

APPENDIX C

CALCULATING THE EFFECTIVE THERMAL RESISTANCE OF BUILDING ENVELOPE ASSEMBLIES

IMPERIAL UNITS

Calculating the Effective Thermal Resistance of Building Envelope Assemblies

The methodology provided in this section allow users to calculate the total effective thermal resistance of common assemblies using the Isothermal Planes method as described in 2009 ASHRAE Handbook-Fundamentals.

In wood frame construction, the Isothermal Planes method breaks the components in an assembly into two types:

(i) A component which has parallel paths of heat flow. The component in which parallel heat flow occurs are assemblies containing both framing members and another material within the cavity, typically an insulation material which makes up the framing-cavity component.

(ii) Continuous layers of homogeneous materials which are included in series. Continuous layers in series are materials that overlay the frame-cavity component such as sheathing and gypsum board.

The Isothermal Planes calculation can be described as:

$$R_{eff} = R_{series} + R_{parallel}$$

Where:

R_{eff} = total effective thermal resistance of the assembly
R_{series} = continuous layers to the exterior and interior of the frame-cavity component
$R_{parallel}$ = effective thermal resistance of the frame-cavity component only

1. Calculate the effective thermal resistance of all layers with continuous materials

   R_{series} = R (external layers) + R (internal layers)

2. Calculate the effective thermal resistance of the framing portion, $R_{parallel}$, using the following equation:

$$R_{parallel} = \frac{100}{\frac{\%\ area\ of\ framing}{Rf} + \frac{\%\ area\ of\ cavity}{Rc}}$$

Where:

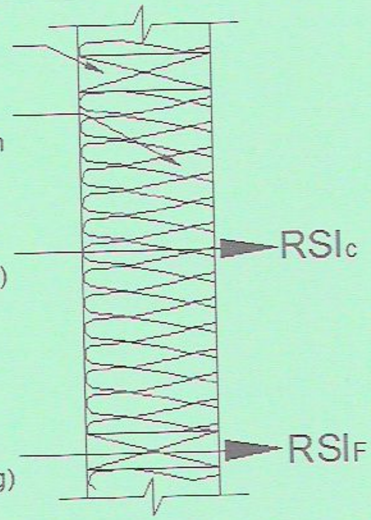
R_f = thermal resistance of the framing member obtained from Appendix B
R_c = thermal resistance of cavity (usually filled with insulation) obtained from Appendix B
% area of framing = value between 0 and 100 obtained from Table 1.
% area of cavity = value between 0 and 100 obtained from Table 1.

Table 1: Framing and Cavity Percentages for Typical Wood-frame Assemblies

Wood-frame Assemblies		Frame Spacing, inch o.c									
		12"		16"		19.2"		24"		48"	
		% Area Framing	% Area Cavity	% Area Framing	% Area Cavity	% Area Framing	% Area Cavity	% Area Framing	% Area Cavity	% Area Framing	% Area Cavity
Floors	Lumber joists	-	-	13	87	11.5	88.5	10	90	-	-
	I-joints and truss	-	-	9	91	7.5	92.5	6	94	-	-
Roofs/ Ceilings	Ceilings with typical trusses	-	-	14	86	12.5	87.5	11	89	-	-
	Ceilings with raised heel trusses	-	-	10	90	8.5	91.5	7	93	-	-
	Roofs with lumber rafters and ceiling with lumber joists	-	-	13	87	11.5	88.5	10	90	-	-
	Roofs with I-joist rafters and ceilings with I-joists	-	-	9	91	7.5	92.5	6	94	-	-
	Roofs with structural insulated panels (SIPs)	-	-	-	-	-	-	-	-	9	91
Walls	Typical wood-frame	24.5	75.5	23	77	21.5	78.5	20	80	-	-
	Advanced wood frame with double top plate	-	-	19	81	17.5	82.5	16	84	-	-
	SIPs	-	-	-	-	-	-	-	-	14	86
	Basement wood-frame inside concrete foundation wall	-	-	16	84	14.5	85.5	13	87	-	-

Example 1

Calculation of R_{eff} for a typical 1.5 x 5.5 inch Wood-frame Wall assembly using the Isothermal-planes method



1. Determine the thermal resistance of each continuous material layer incorporated in the assembly, R_{series}, using Appendix B.
2. Calculate the thermal resistance of a section of framing and adjacent cavity portion, $R_{parallel}$, using the method as follows;
   a) Along a line that goes through the framing, which is designated R_f
   b) Along a line that goes through the cavity (usually filled with insulation), which is designated R_c.

   Look up the % area of framing and cavity for a typical 1.5 x 5.5 inch wood- frame wall assembly with stud's 16 inch o.c. using appendix B:

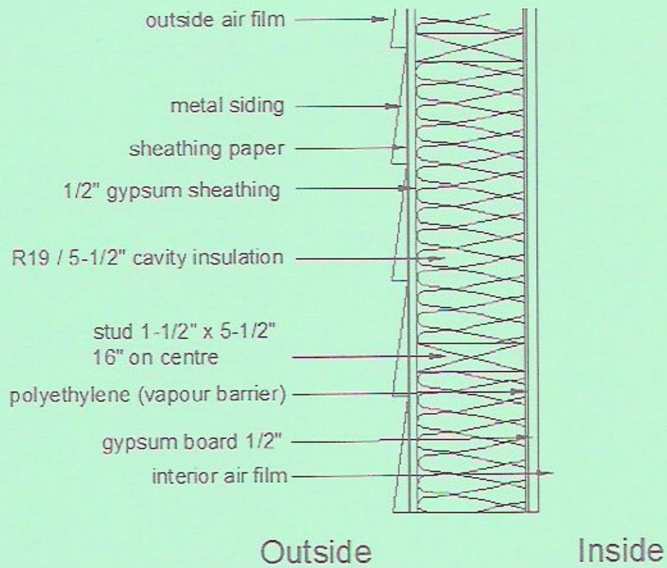
   %area of framing = 23% and
   %area of cavity = 77%

   Then, combine the sums of R_f and R_c in proportion to the relative areas of framing and insulation to calculate the value of $R_{parallel}$ (thermal resistance of the framing portion):

$$R_{parallel} = \frac{100}{\frac{\%\,area\ of\ framing}{Rf} + \frac{\%\,area\ of\ cavity}{Rc}}$$

$$R_{parallel} = \frac{100}{\frac{23}{6.77} + \frac{77}{19}} = 13.42\ \text{h.ft}^2\text{•°F/Btu}$$

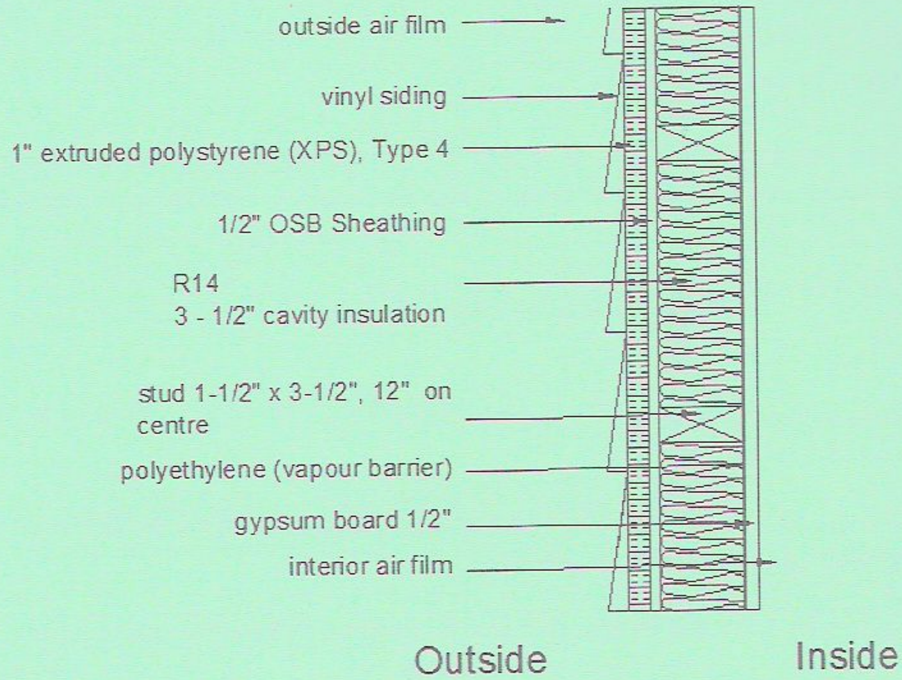
3. Add up the values obtained in steps 1 and 2 to determine the effective thermal resistance of the wall assembly, R_{eff} as follows:



Layers in 1.5 x 5.5 in wood-frame wall assembly with studs spaced 16 in o.c.	h.ft²•°F/Btu
Outside air film	0.17
Metal Siding	0.62
Sheathing paper	-
Gypsum sheathing (0.5 in)	0.46
Stud (5.5 in x 1.23 R/in) Rf = 6.77 (% area framing = 23%) Insulation (5.5 in) Rc = 19 (% area framing = 77%)	RSIparallel = 13.42
Polyethylene (Vapour barrier)	-
Gypsum – interior finish (0.5 in)	0.44
Interior air film	0.68
	Reff = 15.79 h.ft²•°F/Btu

Example 2

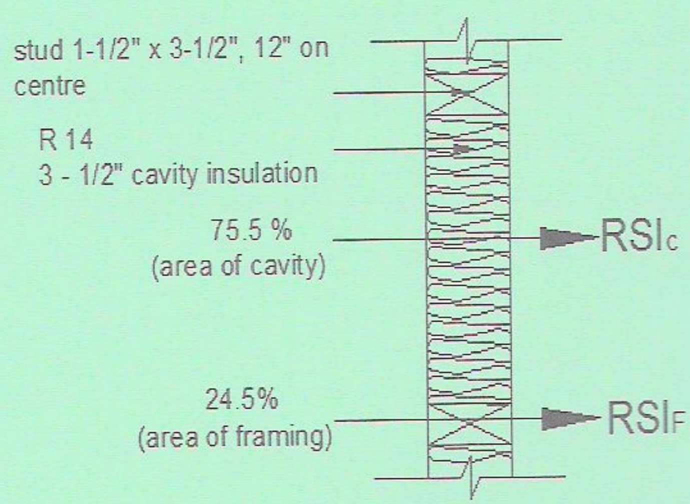
Calculation of R_{eff} for a typical 1.5 x 3.5 in Wood-frame Wall assembly using the Isothermal-planes method



1. Determine the thermal resistance of each continuous material layer incorporated in the assembly R_{series}, using Appendix B.
2. Calculate the thermal resistance of a section of framing and adjacent cavity portion, $R_{parallel}$, using the method as follows;

   c) Along a line that goes through the framing, which is designated R_f

   d) Along a line that goes through the cavity (usually filled with insulation), which is designated R_c.



Look up the % area of framing and cavity for a typical 1.5 x 3.5 in wood- frame wall assembly with studs 12" inch o.c. using Appendix B:

%area of framing = 24.5% and
%area of cavity = 75.5 %

Then, combine the sums of R_f and R_c in proportion to the relative areas of framing and insulation to calculate the value of $R_{parallel}$ (thermal resistance of the framing portion):

$$R_{parallel} = \frac{100}{\frac{\%\,area\ of\ framing}{Rf} + \frac{\%\,area\ of\ cavity}{Rc}}$$

$$R_{parallel} = \frac{100}{\frac{24.5}{4.31} + \frac{75.5}{14}} = 9.03\ \text{h.ft}^2\bullet{}^\circ\text{F/Btu}$$

3. Add up the values obtained in steps 1 and 2 to determine the effective thermal resistance of the wall assembly, R_{eff} as follows:

Layers in 1.5 x 3.5 in wood-frame wall assembly with studs spaced 12 in o.c.	**h.ft²•°F /Btu**
Outside air film	0.17
Siding, Vinyl, hollow-backed	0.62
Extruded polystyrene (XPS), Type 4, 1" inch	5.05
OSB sheathing, 0.5 inch	0.71
Stud 1.5 x 3.5 in RF = 4.31 % area framing = 24.5 % Insulation Rc = 14 % area cavity = 75.5 %	9.03
Polyethylene (Vapour barrier)	0
Gypsum – interior finish (0.5 inch)	0.44
Interior air film	0.68
	R_{eff} = 16.70 h.ft²•°F/Btu

Note: Polyethylene Vapour retarder has a negligible contribution to effective thermal resistance

Tables for Calculating Effective Thermal Resistance of Opaque Assemblies

Natural Resources Canada (NRCan) has developed a document that provides designers with simple, easy-to-use look-up tables for the effective thermal resistance portions of assemblies containing both framing members and cavity insulation, as well as continuous layers (including air films). Essentially R_{series} and $R_{parallel}$ are accounted for in these tables.

For most assemblies, the tables are organized as follows:

i. Type of assembly (e.g. walls above grade)
ii. Type of framing (e.g. dimensional lumber)
iii. Framing member size (e.g. 2" x 6")
iv. Framing on-centre spacing (e.g. 16") within each table

An example of a table is provided below for reference:

Walls Above and Not in Contact with Ground

Table WA-1
Walls Above Grade - Lumber Studs[1]
(Walls Above and Not in Contact with Ground)
Stud dimensional lumber - 38 mm x 89 mm (2"x4") with RSI=0.757 m²K/W

Cavity Insulation Component (Nominal Thermal Resistance)		Framing Configuration[2] (on-centre spacing)			
		304 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")
		Effective Thermal Resistance			
RSI	R	RSI	RSI	RSI	RSI
1.59	9	1.25	1.27	1.29	1.30
1.76	10	1.33	1.35	1.37	1.39
1.94	11	1.40	1.43	1.45	1.48
2.11	12	1.47	1.49	1.52	1.55
2.29	13	1.53	1.56	1.59	1.63
2.46	14	1.59	1.62	1.66	1.70
2.64	15	1.64	1.68	1.72	1.76
2.82	16	1.69	1.73	1.78	1.82
2.99	17	1.74	1.78	1.83	1.88
3.17	18	1.78	1.83	1.88	1.94
3.34	19	1.82	1.87	1.93	1.98
3.52	20	1.86	1.91	1.97	2.03
3.70	21	1.89	1.95	2.01	2.08

NOTES:

1) Continuous surface air films that are eligible to be added: Exterior air film 0.03 m²K/W, and interior wall air film 0.12 m²K/W.

2) Frame-Cavity Percentage	304 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")
	24.5% frame 75.5% cavity	23% frame 77% cavity	21.5% frame 78.5% cavity	20% frame 80% cavity

Tables for Calculating Effective Thermal Resistance of Opaque Assemblies

Natural Resources Canada (NRCan) has developed a document that provides designers with simple, easy-to-use look-up tables for the effective thermal resistance portions of assemblies containing both framing members and cavity insulation, as well as continuous layers (including air films). Essentially R_{series} and $R_{parallel}$ are accounted for in these tables.

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		304 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")
		Effective Thermal Resistance			
RSI	R	RSI	RSI	RSI	RSI
1.59	9	1.25	1.27	1.29	1.30
1.76	10	1.33	1.35	1.37	1.39
1.94	11	1.40	1.43	1.45	1.48
2.11	12	1.47	1.49	1.52	1.55
2.29	13	1.53	1.56	1.59	1.63
2.46	14	1.59	1.62	1.66	1.70
2.64	15	1.64	1.68	1.72	1.76
2.82	16	1.69	1.73	1.78	1.82
2.99	17	1.74	1.78	1.83	1.88
3.17	18	1.78	1.83	1.88	1.94
3.34	19	1.82	1.87	1.93	1.98
3.52	20	1.86	1.91	1.97	2.03
3.70	21	1.89	1.95	2.01	2.08

NOTES:

1) Continuous surface air films that are eligible to be added: Exterior air film 0.03 m²K/W, and interior wall air film 0.12 m²K/W.

2) Frame-Cavity Percentage	304 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")
	24.5% frame 75.5% cavity	23% frame 77% cavity	21.5% frame 78.5% cavity	20% frame 80% cavity

APPENDIX A

RSI VALUES AND HEAT GAIN FACTOR

SI UNITS

INSTRUCTIONS FOR CALCULATING ASSEMBLY RSI VALUES

Tables 1 and Appendix B can be used to determine the assembly or effective RSI values for most wood framed wall, floor and ceiling assemblies.

Table 1 lists the combined RSI-values of the cavity insulation and wood framing only and the values are based on the Isothermal Planes method described in Section 9.36 of the National Building Code and the ASHRAE Book of Fundamentals. The RSI-values that are listed in Table 1 are developed under the assumption of solid lumber framing with 16" (406 mm) centres; 23% framing, 77% insulation. Designers may choose to use the detailed calculations shown in Appendix C if they want more precise results.

RSI values for assemblies with steel framing or with no framing (Insulated Concrete Forms (ICFs) or Structural Insulated Panels (SIPs) need to be determined based on the detailed calculations in Appendix C. Floors and ceilings framed with engineered joists or open web joists will have slightly higher RSI values than determined from these Tables due to reduced framing losses and may also be determined based on Appendix C for increased precision

Step 1) Determine the nominal (insulation only) RSI value of the cavity insulation of the building assembly using the provided drawings, insulation specifications such as CCMC reports, RSI values in Appendix B based on the thickness of the insulation.

- The thickness of the insulation is equal to the depth of the framing members for the assembly **only** if the cavity is full of insulation
- For ceilings with attic spaces where the insulation exceeds the depth of the bottom cord of the truss or framing material, use the depth of the framing material for **Step 1** and use the balance of the insulation in **Step 3**.

Step 2) Look up the Effective RSI value of the Assembly in Table 1 based on the Nominal RSI Value found in **Step 1** and the Framing Depth.

- RSI values below the solid line are not included since they are impossible to achieve using conventional insulation materials (greater than 0.0485 RSI/mm = 7 R/in) based on the depth of the framing material.
- Batt insulation with nominal RSI values based on an uncompressed thickness that is greater than the framing depth should not be used. Use Appendix B RSI values based on the framing depth.
- Use the 2x12 column for Headers.

Step 3) Add the RSI value of any continuous layers(e.g. exterior siding, continuous insulation without farming, sheathing, drywall and inside/outside air films) to the result of **Step 2** using the RSI values from the provided drawings, insulation specifications such as CCMC reports, Values in Appendix B.

Table 1: Effective RSI Value for Wood Framed Assemblies (based on 16" centres with 23% Framing)

Nominal RSI	Framing Size: 2x2, 1x2 or 1 x4 strapping	2x4	2x6	2x8	2x10	2x12 or Headers
Uninsulated Air Cavity	0.20	0.22	0.22	0.23	0.23	0.23
0.35	0.35	0.40	0.42	0.43	0.44	0.44
0.70	0.55	0.72	0.78	0.81	0.83	0.84
1.06	0.70	0.97	1.08	1.15	1.19	1.22
1.41	0.80	1.18	1.35	1.45	1.52	1.57
1.76	0.87	1.35	1.59	1.73	1.82	1.89
2.11		1.50	1.79	1.98	2.10	2.19
2.47		1.62	1.98	2.20	2.36	2.47
2.82		1.73	2.15	2.41	2.60	2.74
3.17		1.83	2.29	2.60	2.82	2.98
3.52		1.92	2.43	2.78	3.03	3.22
3.87		1.99	2.55	2.94	3.22	3.44
4.23		2.06	2.66	3.09	3.40	3.64
4.58			2.77	3.23	3.57	3.84
4.93			2.86	3.36	3.73	4.02
5.28			2.95	3.48	3.88	4.20
5.64			3.03	3.59	4.03	4.37
5.99			3.11	3.70	4.16	4.53
6.34			3.18	3.80	4.29	4.68
6.69			3.25	3.90	4.41	4.82
7.04				3.99	4.52	4.96
7.40				4.07	4.63	5.09
7.75				4.15	4.74	5.22
8.10				4.23	4.84	5.34
8.45				4.30	4.93	5.45
8.81				4.37	5.02	5.56
9.16				4.43	5.11	5.67
9.51					5.19	5.77
9.86					5.27	5.87
10.21					5.34	5.96
10.57					5.42	6.05

Summary: The effective RSI Value of the assembly is:

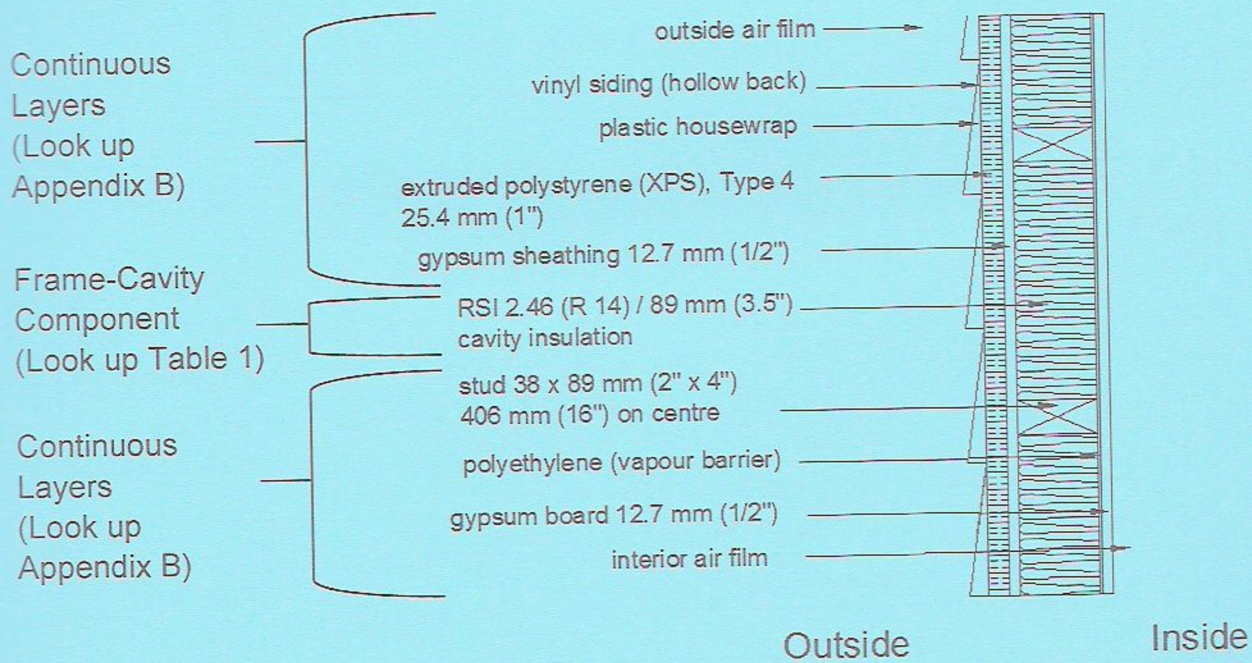
Effective RSI Value of the cavity and framed assembly only
+
Nominal RSI Value of Continuous Layers

OR

Step 2 (Table 1)
+
Step 3 (Appendix B)

Students are encouraged to use the following RSI-value calculation worksheet provided below. A sample calculation is also provided.

Sample Calculation: RSI-value Calculation of Wood Framed Wall



Sample Calculation: RSI-value Calculation of Wood Framed Wall (Cont'd)

Structure	Wood Framed Wall	
Layer	RSI-Value	Reference
Outside air film - walls	0.03	App. B, B-2
Vinyl siding – hollow backed	0.11	App. B, B-2
Plastic Housewrap	-	-
25.4 mm extruded polystyrene (Type 4)	0.89	App. B, B-3
12.7 mm gypsum sheathing	0.08	App. B, B-4
Frame-Cavity: 38 x 89 mm wood stud, 406 mm o.c. filled with RSI2.46 batt	1.98	Table 1
Polyethylene vapour barrier	-	-
12.7 mm gypsum board (interior finish)	0.08	App. B, B-5
Inside air film	0.12	App. B, B-2
TOTAL EFFECTIVE RSI-VALUE	3.29	

Note: R-values for polyethylene vapour barrier and housewrap are considered to be negligible.

RSI-VALUE CALCULATION WORKSHEET

Structure		
Layer	**RSI-Value**	**Reference**
TOTAL EFFECTIVE RSI-VALUE		

Structure		
Layer	**RSI-Value**	**Reference**
TOTAL EFFECTIVE RSI-VALUE		

WINDOWS, SKYLIGHTS, SLIDING GLASS DOORS AND GLAZED PORTIONS OF DOORS

Table 2: RSI value and SHGC of single glazed windows

Frame Material	Storm	RSI value	SHGC
Fixed - Aluminum	No	0.15	0.73
	Yes	0.23	0.65
Fixed - Wood	No	0.19	0.67
	Yes	0.33	0.60
Operable - Aluminum	No	0.13	0.71
	Yes	0.20	0.63
Operable - Wood	No	0.21	0.55
	Yes	0.33	0.49

Note: There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative RSI values and SHGC.

Table 3: RSI value and SHGC of double glazed windows

Frame Material	Spacer	Coatings	Glazing spacing									
			6 mm				9 mm		13 mm			
			Air		Argon		Krypton		Air		Argon	
			RSI value	SHGC	RSI value	SHGC	RSI value	SHGC	RSI value	SHGC	RSI value	SHGC
Fixed - Aluminum	Metal	Clear	0.22	0.65	0.22	0.65	0.24	0.65	0.23	0.65	0.24	0.65
		Low-E	0.25	0.47	0.27	0.47	0.31	0.47	0.28	0.47	0.30	0.47
	Insulating	Clear	0.22	0.65	0.23	0.65	0.25	0.65	0.24	0.65	0.25	0.65
		Low-E	0.26	0.47	0.29	0.47	0.33	0.47	0.30	0.47	0.32	0.47
Fixed - Wood/Vinyl	Metal	Clear	0.30	0.60	0.32	0.60	0.35	0.60	0.33	0.60	0.35	0.60
		Low-E	0.36	0.47	0.41	0.47	0.51	0.47	0.45	0.47	0.45	0.47
	Insulating	Clear	0.32	0.59	0.35	0.59	0.38	0.59	0.36	0.59	0.38	0.59
		Low-E	0.40	0.47	0.47	0.47	0.59	0.47	0.51	0.47	0.57	0.47
Operable - Aluminum	Metal	Clear	0.19	0.63	0.19	0.63	0.20	0.63	0.20	0.63	0.20	0.63
		Low-E	0.21	0.47	0.22	0.47	0.33	0.47	0.23	0.47	0.24	0.47
	Insulating	Clear	0.19	0.63	0.20	0.63	0.21	0.63	0.20	0.63	0.21	0.63
		Low-E	0.21	0.47	0.29	0.47	0.26	0.47	0.24	0.47	0.26	0.47
Operable - Wood/Vinyl	Metal	Clear	0.37	0.49	0.32	0.49	0.35	0.49	0.33	0.49	0.34	0.49
		Low-E	0.41	0.47	0.39	0.47	0.46	0.47	0.42	0.47	0.45	0.47
	Insulating	Clear	0.41	0.49	0.35	0.49	0.38	0.49	0.36	0.49	0.37	0.49
		Low-E	0.46	0.47	0.44	0.47	0.52	0.47	0.47	0.47	0.51	0.47

NOTE:
1) Rough openings for windows shall be used in the calculations.
2) If space between adjacent panes is less than 6 mm, glazing shall be treated as one layer.
3) There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative RSI values and SHGC.

Table 4: RSI value and SHGC of triple glazed windows with one coating

Frame Material	Spacer	Coatings	Glazing spacing									
			6 mm				9 mm		13 mm			
			Air		Argon		Krypton		Air		Argon	
			RSI value	SHGC	RSI value	SHGC	RSI value	SHGC	RSI value	SHGC	RSI value	SHGC
Fixed - Aluminum	Metal	Clear	0.26	0.58	0.27	0.58	0.29	0.58	0.28	0.58	0.29	0.58
		Low-E	0.28	0.40	0.30	0.40	0.34	0.40	0.32	0.40	0.34	0.40
	Insulating	Clear	0.27	0.58	0.28	0.58	0.31	0.58	0.30	0.58	0.31	0.58
		Low-E	0.30	0.40	0.32	0.40	0.37	0.40	0.34	0.40	0.36	0.40
Fixed - Wood/Vinyl	Metal	Clear	0.39	0.53	0.41	0.53	0.47	0.53	0.44	0.53	0.46	0.53
		Low-E	0.43	0.40	0.49	0.40	0.60	0.40	0.54	0.40	0.59	0.40
	Insulating	Clear	0.43	0.53	0.47	0.53	0.55	0.53	0.52	0.53	0.54	0.53
		Low-E	0.50	0.40	0.57	0.40	0.75	0.40	0.66	0.40	0.73	0.40
Operable - Aluminum	Metal	Clear	0.21	0.57	0.22	0.57	0.24	0.57	0.23	0.57	0.23	0.57
		Low-E	0.23	0.40	0.24	0.40	0.27	0.40	0.25	0.40	0.26	0.40
	Insulating	Clear	0.27	0.58	0.23	0.57	0.25	0.57	0.24	0.57	0.25	0.57
		Low-E	0.30	0.40	0.32	0.40	0.28	0.40	0.27	0.40	0.28	0.40
Operable - Wood/Vinyl	Metal	Clear	0.37	0.44	0.39	0.44	0.44	0.44	0.42	0.44	0.44	0.44
		Low-E	0.41	0.40	0.44	0.40	0.53	0.40	0.49	0.40	0.52	0.40
	Insulating	Clear	0.41	0.44	0.44	0.44	0.52	0.43	0.50	0.43	0.52	0.43
		Low-E	0.46	0.40	0.51	0.40	0.66	0.40	0.60	0.40	0.64	0.40

NOTE:

1) Rough openings for windows shall be used in the calculations.
2) If space between adjacent panes is less than 6 mm, glazing shall be treated as one layer.
3) There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative RSI values and SHGC.

Table 5: RSI value and SHGC of triple glazed windows with two coatings

Frame Material	Spacer	Coatings	Glazing spacing									
			6 mm				9 mm		13 mm			
			Air		Argon		Krypton		Air		Argon	
			RSI value	SHGC	RSI value	SHGC	RSI value	SHGC	RSI value	SHGC	RSI value	SHGC
Fixed - Aluminum	Metal	Low-E	0.30	0.25	0.32	0.25	0.37	0.25	0.34	0.25	0.36	0.25
	Insulating	Low-E	0.32	0.25	0.35	0.25	0.40	0.25	0.37	0.25	0.39	0.25
Fixed - Wood/Vinyl	Metal	Low-E	0.48	0.22	0.54	0.22	0.69	0.22	0.61	0.22	0.67	0.22
	Insulating	Low-E	0.55	0.22	0.64	0.22	0.89	0.22	0.76	0.22	0.86	0.22
Operable - Aluminum	Metal	Low-E	0.24	0.26	0.25	0.26	0.28	0.26	0.27	0.26	0.28	0.26
	Insulating	Low-E	0.25	0.26	0.27	0.26	0.30	0.26	0.28	0.26	0.29	0.26
Operable - Wood/Vinyl	Metal	Low-E	0.44	0.19	0.48	0.19	0.58	0.19	0.53	0.19	0.57	0.19
	Insulating	Low-E	0.50	0.19	0.55	0.19	0.74	0.19	0.66	0.19	0.72	0.19

NOTE:
1) Rough openings for windows shall be used in the calculations.
2) If space between adjacent panes is less than 6 mm, glazing shall be treated as one layer.
3) There are specific measurement tools available for determining the presence of low-e coatings on installed windows. There is no practical way to determine the presence of argon or other gas fillings. There might be identifying marks etched into the spacer material or at the edge of the glass. If the presence of coatings or fillings cannot be determined, designers may wish to choose conservative RSI values and SHGC.

Table 6: RSI value for doors

Doors	Thermal resistance	
	Without storm door	With storm door
Solid wood 44 mm thick	0.53	0.71
Panel type wood 32 mm thick	0.45	0.63
Insulated metal - Polystyrene core	1.00	1.20
Insulated metal - Polyurethane core	1.10	1.30
Insulated fiberglass - Polystyrene core	0.85	1.05
Insulated fiberglass - Polyurethane core	1.00	1.20

Note: Rough openings for doors shall be used in the calculations.

Table 7: Level factors for applying air leakage fractions to room in different levels

Number of levels / Level	One (e.g. slab on grade bungalow)	Two (e.g. bungalow with basement, two-storey slab on grade)	Three (e.g. two-storey house on basement)	Four (e.g. three-storey house on basement)
Lowest Level	1.0	0.6	0.5	0.4
2nd level up		0.4	0.3	0.3
3rd level up			0.2	0.2
4th level up				0.1

Table 8: DUCT MULTIPLIERS

DUCT MULTIPLIERS			
DUCT LOCATION	R-Value of DUCT INSULATION VALUE	DUCT LOSS MULTIPLIER	DUCT GAIN MULTIPLIER
attic or open crawlspace	NONE	0.25	0.25
	0.70	0.15	0.15
	1.40	0.10	0.10
	2.10	0.05	0.05
	3.5 or greater	-----	-----
unconditioned basement	2.10	-----	0.05
enclosed, unconditioned crawlspace	NONE	0.25	0.25
	0.70	0.15	0.15
	1.40	0.10	0.10
	3.50	0.05	0.05
	3.50 or greater	-----	------
slab-on-grade with perimeter insulation	All values	0.10	-----

Note: this table provides adjustment multipliers for heat loss and heat gain calculations for when ducts serving the building or rooms pass through or are located in unconditioned space.

Table 9: PIPE LOSS MULTIPLIERS

PIPE LOSS MULTIPLIERS			
Pipe Heat Flux [W/m2]	TYPE OF CIRCULATION	INSULATED PIPE	UNINSULATED PIPE
100 W/m2 or less	Gravity	0.2	1.0
	Pumped	0.1	0.6
Greater than 100 W/m2	Gravity	0.1	0.5
	Pumped	0.0	0.3

* Based on 25 mm thick insulation with conductivity of 1.42 W/m/C

Table 10: Solar corrections for heat gain calculations – normal procedure

Building Assembly	Solar correction, SC (°C), by Summer Mean Daily Temperature Range	
	Up to and including 14 °C	Over 14 °C
Walls, headers and doors	0	-3
Interior partitions and fully shaded exterior walls, headers and doors	-3	-6
Roofs and top storey ceilings	+15	+12
Floors over non-conditioned rooms and ceilings under non-conditioned rooms	-3	-6

Table 11: Solar corrections for heat gain calculations – detailed procedure

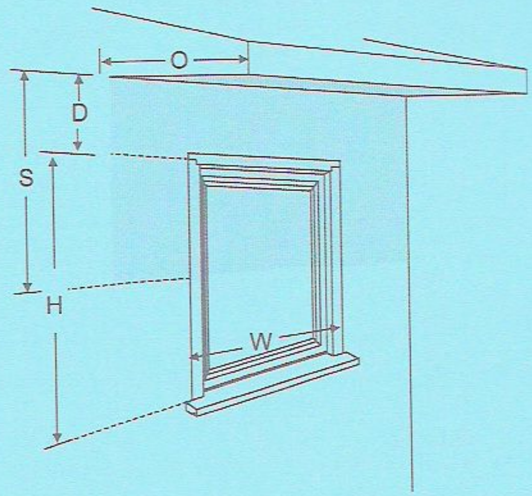
Building Assembly	Orientation	Solar correction, SC (°C), by Summer Mean Daily Temperature Range	
		Up to and including 14 °C	Over 14 °C
Walls, headers and doors	Factor for whole house calculation	0	-3
	North	-4	-7
	Northeast and Northwest	-1	-3
	East and West	+2	-1
	Southeast and Southwest	+1	-2
	South	-2	-5
Interior partitions and fully shaded exterior walls, headers and doors		-3	-6
Roofs and top storey ceilings		+15	+12
Floors over non-conditioned rooms and ceilings under non-conditioned rooms		-3	-6

Note: This chart is only to be used if solar correction is required to be calculated by wall orientation such as when calculating heat gain for row housing or condominiums with exposed walls facing in only 1 or 2 directions. The normal procedure is to use the simplified "Solar corrections for heat gain calculations – normal procedure" chart found at top of this page

CALCULATING SHADED AND UNSHADED AREAS OF WINDOWS

To calculate a window area that is shaded, both the shaded and unshaded areas must be determined.

The following formulas are used to determine the these areas:



i) S = F x O

where: S = Distance to Shade Line
F = Shade Factor (from table below)
O = Width of Overhang (measured)

ii) SHADED AREA = (S - D) × W

where: W= Width of Window (measured)
S = Distance to Shade Line
D = Head Drop (measured)

Note: SHADED AREA can not exceed H x W

iii) UNSHADED AREA = H x W - (SHADED AREA)

Where: H = Window Height (measured)
W = Window Width (measured)

Note: If D is greater than S, then SHADED AREA = 0

Special Note

This manual requires that H and W be measured from the rough frame opening. This allows the window dimensions from the heat loss calculations to also be used in the heat gain calculation.

Table 12: External F-Shade Factors

F Shade Factor							
Direction Window Faces	North Latitude, Degrees						
	40	42.5	45	47.5	50	52.5	55
East/West	0.8						
Southeast/Southwest	1.3	1.2	1.1	1.1	1.0	1.0	0.9
South	2.6	2.3	2.0	1.9	1.7	1.6	1.4

Table13: Estimated solar radiation (W/m2)

North Latitude (°)	North & Shaded Windows	South	East/ West	Northeast/ Northwest	Southeast/ Southwest	Horizontal
40	93	160	285	194	252	534
41	93	166	285	194	261	534
42	93	172	285	194	271	534
43	93	178	285	194	280	534
44	93	184	285	194	290	534
45	93	190	285	194	299	534
46	93	196	285	194	309	534
47	93	202	285	194	318	534
48 to 82	93	208	285	194	328	534

Table 14: Internal shading factors

Type of interior shading	Type of glazing systems			
	Single	Double	Triple	Heat mirror
No interior shades	1	1	1	1
Interior blinds, curtains...etc.	0.50	0.55	0.57	0.60
Interior reflective metallic blinds or screens	0.35	0.37	0.40	0.44
Exterior roll shutters and screen shadings	see Notes (1) and (2)	see Notes (1) and (2)	see Notes (1) and (2)	see Notes (1) and (2)

1) Between-pane reflective metallic blinds, and exterior shutters and screen shadings could generally be treated as walls with respect to solar gain, since the amount of solar transmitted is a small part of the load. In that case, the insulation value of the shade should only be added to the insulation value of the external shutter or shade (if they are fully closed).

2) For exterior shutters and screen shadings, use manufacturer's data when available. To account for both solar and conductive gains, refer to "Guidelines for Effective Residential Solar Shading Devices", Laouadi, A., National Research Council of Canada, March 2010, IRC-RR-300.

Table 15: Principal Ventilation Capacity (PVC)

Table 15a
National Building Code
Table 9.32.3.3
Normal Operating Exhaust Capacity of Principal Ventilation Fan

Number of bedrooms	Capacity			
	Minimum		Maximum	
	CFM	L/s	CFM	L/s
1	34	16	51	24
2	38	18	59	28
3	47	22	68	32
4	55	26	81	38
5	64	30	95	45
More than 5 bedrooms and the system must comply to CSA- F326				

Note: As seen above National building code lists both minimum and maximum requirement for Principal Ventilation Capacity. For ventilation heat loss and heat gain calculation use the maximum PVC.

Table 15b
Ontario Building Code
Table 9.32.3.4.A
Principal Exhaust Fan Capacity

Number of Bedrooms	Capacity	
	CFM	L/s
1	30	15
2	45	22.5
3	60	30
4	75	37.5
5	90	45
More than 5	Part 6 design	

Table 15c

British Columbia Building Code
Table 9.32.3.3.A
Principal Exhaust Fan Ventilation Rate (L/s)
Forming part of clause 9.32.3.3.(1)(a)

Floor Area, m^2	Number of Bedroom*				
	0-1	2-3	4-5	6-7	>7
<140	14	21	28	35	42
140-280	21	28	35	42	49
281-420	28	35	42	49	56
421-560	35	42	49	56	64
561-700	42	49	56	64	71
>700	49	56	64	71	78

Note*: A bedroom is considered as a room with a window conforming to Article 9.9.10.1 and an interior closing door.

APPENDIX B

SUPPLEMENTARY INFORMATION FOR DETAILED R-VALUE CALCULATIONS

SI UNITS

Note(s):

Except where noted, the values listed are taken from the NRCan "Tables for calculating Effective Thermal Resistance of Opaque Assemblies" December 2012 and Table A - 9.36.2.4. (1) D from National building code. Look for NRCan and National Building Code reference for insulation.

This document provides thermal resistance properties of opaque assembly materials required to calculate the total effective thermal resistance of building assemblies under the *2012 ENERGY STAR® for New Homes (ESNH) Standard*. The format is designed to provide simple, easy-to-use look-up tables for the effective thermal resistance of portions of assemblies containing continuous material layers (including air films).

Note*:
Values in Italic are taken from CAN/CSA-F280 Standard.

Thermal Resistance Values for Building Materials			
Description		**Thermal resistance (RSI)**	
		Per mm ($m^2 \cdot °C/W/mm$)	**As listed** ($m^2 \cdot °C/W$)
Air Films			
Exterior:	ceiling, floors and walls wind 6.7 m/s (winter)	-	0.03
Interior:	ceiling (heat flow up)	-	0.11
	floor (heat flow down)	-	0.16
	walls (heat flow horizontal)	-	0.12
Vented Roof Air Space			
Cathedral, flat and attic		-	0.03
Air Cavities			
Air spaces less than or equal to 12 mm, 1/2 inch minimum dimension		-	*negligible*
Ceiling (heat flow up):	13 - 20 mm air space	-	0.15
	21 - 90 mm air space	-	0.16
Floors (heat flow down):	13 - 19 mm air space	-	0.16
	20 – 39 mm air space	-	0.18
	40 - 89 mm air space	-	0.20
	90 mm air space	-	0.22
Walls (heat flow horizontal):	13 – 19 mm air space	-	0.16
	20 – 90 mm air space	-	0.18
Cladding Materials			
Brick:	fired clay (2400 kg/m^2)	0.001	-
	concrete: sand and gravel, or stone (2400 kg/m^2)	0.001	-
Siding:	Fibre-cement	0.003	-
	Hardboard, 11 mm	-	0.12
	Plywood, 9.5 mm -lapped	-	0.10
	Vinyl, hollow-backed	-	0.11
	Vinyl, insulating-board-backed: 9.5 mm nominal	-	0.32
	Wood, 13 mm	-	0.14
Metal Siding:	*Horizontal clapboard profile*	-	*0.12*
	Horizontal clapboard profile with backing	-	*0.25*
	Vertical V-groove profile	-	*0.12*
Stone:	Quartzitic and sandstone (2240 kg/m^3)	0.0003	-
	Calcitic, dolomitic, limestone, marble and granite (2240 kg/m^3)	0.0004	-
Wood Shingles:	400mm, 190mm exposure	-	0.15
	400mm, 3000mm exposure (double exposure)	-	0.21
	insulating backer board	-	0.25
Stucco and mortar, cement/lime		0.0009	-
Roofing Materials			
Asphalt roll roofing		-	0.03
Asphalt/tar		0.0014	-
Build-up roofing		-	0.06
Crushed stone		0.0006	-
Metal deck		-	negligible
Shingle	Asphalt	-	0.08
	Wood	-	0.17
Slate		-	0.01

<table>
<tr><th colspan="4">Thermal Resistance Values for Building Materials</th></tr>
<tr><th colspan="2" rowspan="2">Description</th><th colspan="2">Description</th></tr>
<tr><th>Per mm (m²•°C/W/mm)</th><th>As listed (m²•°C/W)</th></tr>
<tr><td colspan="4">Insulation Materials</td></tr>
<tr><td colspan="4">Blanket and Batt:</td></tr>
<tr><td rowspan="7">Rock or glass fibre (CAN ULC S702)</td><td>R-12 (89/92 mm)</td><td>-</td><td>2.11</td></tr>
<tr><td>R-14 (89/92 mm)</td><td>-</td><td>2.46</td></tr>
<tr><td>R-19 (R-20 batt compressed) (140 mm)</td><td>-</td><td>3.34</td></tr>
<tr><td>R-20 (152 mm)</td><td>-</td><td>3.52</td></tr>
<tr><td>R-22 (140/152 mm)</td><td>-</td><td>3.87</td></tr>
<tr><td>R-22.5 (152 mm)</td><td>-</td><td>3.96</td></tr>
<tr><td>R-24 (140/152 mm)</td><td>-</td><td>4.23</td></tr>
<tr><td rowspan="4">Rock or glass fi bre (CAN ULC S702), cont'd</td><td>R-28 (178/ 216 mm)</td><td>-</td><td>4.93</td></tr>
<tr><td>R-31 (241 mm)</td><td>-</td><td>5.46</td></tr>
<tr><td>R-35 (267 mm)</td><td>-</td><td>6.16</td></tr>
<tr><td>R-40 (279/300 mm)</td><td>-</td><td>7.04</td></tr>
<tr><td colspan="4">Boards and Slabs:</td></tr>
<tr><td rowspan="2">Polyisocyanurate (PIR) and Polyurethane (PUR) Board CAN/ULC S704)</td><td>Permeably faced</td><td>0.038</td><td>-</td></tr>
<tr><td>Impermeably faced</td><td>0.039</td><td>-</td></tr>
<tr><td rowspan="3">Expanded Polystyrene Insulation Board (EPS) (CAN/ULC S701)</td><td>Type 1</td><td>0.026</td><td>-</td></tr>
<tr><td>Type 2</td><td>0.028</td><td>-</td></tr>
<tr><td>Type 3</td><td>0.031</td><td>-</td></tr>
<tr><td>Extruded Polystyrene Insulation Board (XPS) (CAN/ULC S701)</td><td>Types 2, 3& 4</td><td>0.035</td><td>-</td></tr>
<tr><td colspan="2">Rock fibre semi-rigid board</td><td>0.028</td><td>-</td></tr>
<tr><td colspan="2">Glass fibre semi-rigid board</td><td>0.030</td><td>-</td></tr>
<tr><td colspan="2">Roof board</td><td>0.018</td><td>-</td></tr>
<tr><td colspan="2">Building board or ceiling tile, lay-in panel</td><td>0.016</td><td>-</td></tr>
<tr><td colspan="2">Natural Cork</td><td>0.026</td><td>-</td></tr>
<tr><td colspan="2">Phenolic thermal insulation</td><td>0.030</td><td>-</td></tr>
<tr><td colspan="4">Spray-Applied:</td></tr>
<tr><td colspan="2">Sprayed polyurethane foam, medium density closed cell (CAN/ULC S705.1)</td><td>0.036</td><td>-</td></tr>
<tr><td colspan="2">Sprayed polyurethane foam, light density open cell (CAN/ULC S705.1)</td><td>0.026</td><td>-</td></tr>
<tr><td colspan="2">Sprayed Cellulosic fi bre (settled thickness)</td><td>0.024</td><td>-</td></tr>
<tr><td colspan="2">Spray-applied glass-fibre insulation: 16 kg/m³ (CAN/ULC S702)</td><td>0.025</td><td>-</td></tr>
<tr><td colspan="2">Sprayed Asbestos</td><td>0.020</td><td>-</td></tr>
<tr><td colspan="4">Loose-fill insulation:</td></tr>
<tr><td colspan="2">Wood shavings</td><td>0.017</td><td>-</td></tr>
<tr><td colspan="2">Cellulose (CAN/ULC S703)</td><td>0.025</td><td>-</td></tr>
<tr><td colspan="2">Glass fibre loose fill insulation for attics - 112 mm to 565 mm (CAN/ULC S702)</td><td>0.019</td><td>-</td></tr>
<tr><td colspan="2">Glass fibre loose fill insulation for walls (CAN/ULC S702)</td><td>0.028</td><td>-</td></tr>
<tr><td colspan="2">Perlite</td><td>0.019</td><td></td></tr>
<tr><td colspan="2">Vermiculite</td><td>0.015</td><td></td></tr>
</table>

Thermal Resistance Values for Building Materials			
Description		Thermal resistance (RSI)	
		Per mm ($m^2 \cdot °C/W/mm$)	As listed ($m^2 \cdot °C/W$)
Sheet Materials			
Gypsum board (sheathing)		0.0063	-
Insulating fibreboard (Type 2 sheathing)		0.016	-
Plywood (generic softwood)		0.0087	-
Plywood, Douglas-fir		0.0111	-
Oriented strand board (OSB)		0.0098	-
Particleboard	low density ($593 kg/m^3$)	0.0098	-
	medium density ($800 kg/m^3$)	0.0077	-
	high density ($993 kg/m^3$)	0.0059	-
Sheet Materials	permeable felt	-	0.011
	seal, 2 layers of mopped ($0.73 kg/m^3$)	-	0.21
	seal, plastic film	-	negligible
Waferboard ($705 kg/m^3$)		0.0095	-
Structural Materials			
Concrete	Sand and gravel or stone aggregate ($2400 kg/m^3$)	0.0004	-
	Expanded shale, clay, slate or slags, cinders ($1600 kg/m^3$)	0.0013	-
	Perlite, vermiculite and polystyrene bead ($480 kg/m^3$)	0.0063	-
Hardwood	Ash	0.0063	-
	Birch	0.0055	-
	Maple	0.0063	-
	Oak	0.0053	-
SoftWood	Amabilis fir	0.008	-
	California redwood	0.0089	-
	Douglas fir-larch	0.0069	-
	Eastern white ceder	0.0099	-
	Eastern White pine	0.0092	-
	Hemlock-fir	0.0084	-
	Lodgepole pine	0.0082	-
	Red pine	0.0077	-
	Western hemlock	0.0074	-
	Western red cedar	0.0102	-
	White spruce	0.0097	-
	Yellow cyprus-cedar	0.0077	-
Wood, structural framing, spruce-pine-fir		0.0085	-
Steel, galvanized sheet, 0.14% carbon content		0.0000161	-

Thermal Resistance Values for Building Materials				
Description			Thermal resistance (RSI) Per mm (m²•°C/W/mm)	Thermal resistance (RSI) As listed (m²•°C/W)
Interior Finish Materials				
Gypsum board			0.0061	-
Hardboard- medium desnity (800kg/m³)			0.010	-
Interior finish (plank, tile) board			0.020	-
Flooring material	carpet and fibrous pad		-	0.37
	carpet and rubber pad		-	0.22
	cork tile		-	0.049
	Hardwood flooring		-	0.12
	Terrazzo		-	0.014
	Tile (linoleum,vinyl,rubber)		-	0.009
	Tile (ceramic)		-	0.005
	Wood subfloor		-	0.17
	Wood fibre tiles - 13mm, 1/2 inch		-	*0.209*
Plastering	Cement plaster: sand aggregate		0.0014	-
Gypsum plaster	low density aggregate		0.0044	-
	sand aggregate		0.0012	-
Hollow clay Bricks				
Multi-cored without insulation in cores			-	0.27
Rectangular 2-core	no insulation in cores	140mm	-	0.39
		190mm	-	0.41
		290mm	-	0.47
	cores filled with vermiculite	140mm	-	0.65
		190mm	-	0.86
		290mm	-	1.29
Rectangular 3-core	no insulation in cores	90mm	-	0.35
		140mm	-	0.38
		190mm	-	0.41
		240mm	-	0.43
		290mm	-	0.45
	cores filled with vermiculite	140mm	-	0.68
		190mm	-	0.86
		240mm	-	1.06
		290mm	-	1.19

Thermal Resistance Values for Building Materials				
Description			Thermal resistance (RSI)	
			Per mm (m²•°C/W/mm)	As listed (m²•°C/W)
Concrete Blocks				
Limestone aggregate with 2 cores cores filled with perlite		190mm	-	0.37
		290mm	-	0.65
Light Weight units (expanded shale, clay, slate or slag aggregate) with 2 or 3 cores	no insulation in cores	90mm	-	0.24
		140mm	-	0.3
		190mm	-	0.32
		240mm	--	0.33
		290mm	-	0.41
	cores filled with perlite	140mm	-	0.74
		190mm	-	0.99
		290mm	-	1.35
	cores filled with vermiculite	140mm	-	0.58
		190mm	-	0.81
		240mm	-	0.98
		290mm	-	1.06
	cores filled with molded EPS beads	190mm	-	0.85
	molded EPS inserts in cores	190mm	-	0.62
Medium weight units (combination of normal and low mass aggregate) with 2 or 3 cores.	no insulation in cores	190mm	-	0.26
	cores filled with molded EPS beads		-	0.56
	molded EPS inserts in cores		-	0.47
	cores filled with perlite		-	0.53
	cores filled with vermiculite		-	0.58
Normal weight units (sand and gravel aggregate) with 2 or 3 cores	no insulation in cores	90mm	-	0.17
		140mm	-	0.19
		190mm	-	0.21
		240mm	-	0.24
		290mm	-	0.26
	cores filled with perlite	190mm	-	0.35
	cores filled with vermiculite	140mm	-	0.4
		190mm	-	0.51
		240mm	-	0.61
		290mm	-	0.69

APPENDIX C

CALCULATING THE EFFECTIVE THERMAL RESISTANCE OF BUILDING ENVELOPE ASSEMBLIES

SI UNITS

Calculating the Effective Thermal Resistance of Building Envelope Assemblies

The methodology provided in this section allow users to calculate the total effective thermal resistance of common assemblies using the Isothermal Planes method as described in 2009 ASHRAE Handbook-Fundamentals.

In wood frame construction, the Isothermal Planes method breaks the components in an assembly into two types:

(i) A component which has parallel paths of heat flow. The component in which parallel heat flow occurs are assemblies containing both framing members and another material within the cavity, typically an insulation material which makes up the framing-cavity component.

(ii) Continuous layers of homogeneous materials which are included in series. Continuous layers in series are materials that overlay the frame-cavity component such as sheathing and gypsum board.

The Isothermal Planes calculation can be described as:

$$RSI_{eff} = RSI_{series} + RSI_{parallel}$$

Where:

RSI_{eff} = total effective thermal resistance of the assembly
RSI_{series} = continuous layers to the exterior and interior of the frame-cavity component
$RSI_{parallel}$ = effective thermal resistance of the frame-cavity component only

1. Calculate the effective thermal resistance of all layers with continuous materials

   RSI_{series} = RSI (external layers) + RSI (internal layers)

2. Calculate the effective thermal resistance of the framing portion, $RSI_{parallel}$, using the following equation:

$$RSI_{parallel} = \frac{100}{\frac{\%\ area\ of\ framing}{RSIf} + \frac{\%\ area\ of\ cavity}{RSI\ c}}$$

Where:

RSI_F = thermal resistance of the framing member obtained from Appendix B
RSI_c = thermal resistance of cavity (usually filled with insulation) obtained from Appendix B

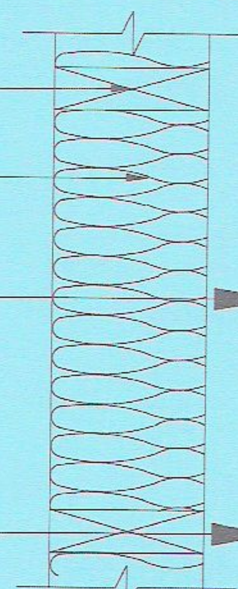
% area of framing = value between 0 and 100 obtained from Table 1.
% area of cavity = value between 0 and 100 obtained from Table 1.

Table 1: Framing and Cavity Percentages for Typical Wood-frame Assemblies

Wood-frame Assemblies		Frame Spacing, mm o.c									
		304		406		488		610		1220	
		% Area Framing	% Area Cavity	% Area Framing	% Area Cavity	% Area Framing	% Area Cavity	% Area Framing	% Area Cavity	% Area Framing	% Area Cavity
Floors	Lumber joists	-	-	13	87	11.5	88.5	10	90	-	-
	I-joints and truss	-	-	9	91	7.5	92.5	6	94	-	-
Roofs/ Ceilings	Ceilings with typical trusses	-	-	14	86	12.5	87.5	11	89	-	-
	Ceilings with raised heel trusses	-	-	10	90	8.5	91.5	7	93	-	-
	Roofs with lumber rafters and ceiling with lumber joists	-	-	13	87	11.5	88.5	10	90	-	-
	Roofs with I-joist rafters and ceilings with I-joists	-	-	9	91	7.5	92.5	6	94	-	-
	Roofs with structural insulated panels (SIPs)	-	-	-	-	-	-	-	-	9	91
Walls	Typical wood-frame	24.5	75.5	23	77	21.5	78.5	20	80	-	-
	Advanced wood frame with double top plate	-	-	19	81	17.5	82.5	16	84	-	-
	SIPs	-	-	-	-	-	-	-	-	14	86
	Basement wood-frame inside concrete foundation wall	-	-	16	84	14.5	85.5	13	87	-	-

Example 1

Calculation of RSI_{eff} for a typical 38 x 140mm Wood-frame Wall assembly using the Isothermal-planes method



1. Determine the thermal resistance of each continuous material layer incorporated in the assembly, RSI_{series}, using Appendix B.
2. Calculate the thermal resistance of a section of framing and adjacent cavity portion, $RSI_{parallel}$, using the method as follows;
    a) Along a line that goes through the framing, which is designated RSI_f
    b) Along a line that goes through the cavity (usually filled with insulation), which is designated RSI_c.

Look up the % area of framing and cavity for a typical 38 x 140mm wood- frame wall assembly with studs 406mm o.c. using appendix B:

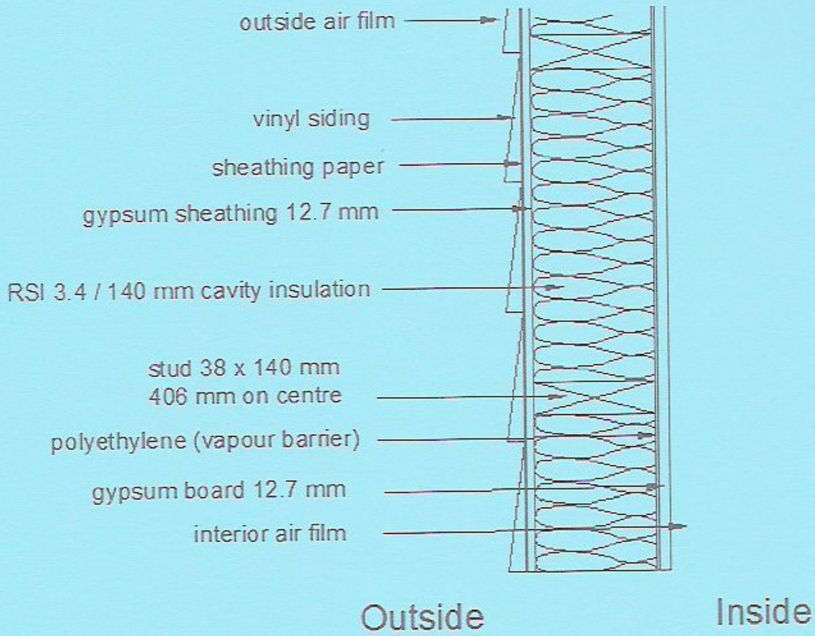
%area of framing = 23% and
%area of cavity = 77%

Then, combine the sums of RSI_F and RSI_c in proportion to the relative areas of framing and insulation to calculate the value of $RSI_{parallel}$ (thermal resistance of the framing portion):

$$RSI_{parallel} = \frac{100}{\frac{\%\ area\ of\ framing}{RSIf} + \frac{\%\ area\ of\ cavity}{RSIc}}$$

$$RSI_{parallel} = \frac{100}{\frac{23}{1.19} + \frac{77}{3.4}} = 2.38\ (m^2.K)/W$$

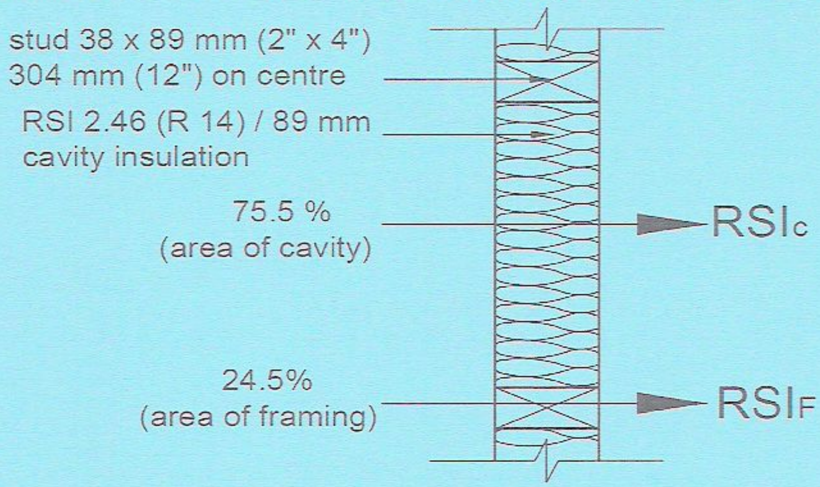
3. Add up the values obtained in steps 1 and 2 to determine the effective thermal resistance of the wall assembly, RSI_{eff} as follows:



Layers in 38 x 140mm wood-frame wall assembly with studs spaced 406 mm o.c.	RSI $(m^2 \cdot K)/W$
Outside air film	0.03
Vinyl Siding (hollow backed)	0.11
Sheathing paper	-
Gypsum sheathing (12.7mm)	0.08
Stud 38 x 140 mm RSIf = 1.19 % area framing = 23 % Insulation RSIc = 3.4 % area cavity = 77 %	$RSI_{parallel}$ = 2.38
Polyethylene (Vapour barrier)	-
Gypsum – interior finish (12.7mm)	0.08
Interior air film	0.12
	RSI_{eff} = 2.80 $(m^2.K)/W$

Example 2

Calculation of RSI_{eff} for a typical 38 x 89mm Wood-frame Wall assembly using the Isothermal-planes method



1. Determine the thermal resistance of each continuous material layer incorporated in the assembly, RSI_{series} , using Appendix B.
2. Calculate the thermal resistance of a section of framing and adjacent cavity portion, $RSI_{parallel}$, using the method as follows;

    c) Along a line that goes through the framing, which is designated RSI_f

    d) Along a line that goes through the cavity (usually filled with insulation), which is designated RSI_c.

Look up the % area of framing and cavity for a typical 38 x 89mm wood- frame wall assembly with studs 304mm o.c. using Appendix B:

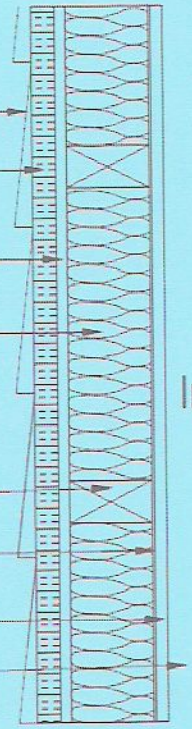
%area of framing = 24.5% and
%area of cavity = 75.5 %

Then, combine the sums of RSI_f and RSI_c in proportion to the relative areas of framing and insulation to calculate the value of $RSI_{parallel}$ (thermal resistance of the framing portion):

$$RSI_{parallel} = \frac{100}{\frac{\%\,area\ of\ framing}{RSIf} + \frac{\%\,area\ of\ cavity}{RSIc}}$$

$$RSI_{parallel} = \frac{100}{\frac{24.5}{0.757} + \frac{75.5}{2.46}} = 1.59\ (m^2.K)/W$$

3. Add up the values obtained in steps 1 and 2 to determine the effective thermal resistance of the wall assembly, RSI_{eff} as follows:



Layers in 38 x 89mm wood-frame wall assembly with studs spaced 304 mm o.c.	**RSI (m²·K)/W**
Outside air film	0.03
Siding, Vinyl, hollow-backed	0.11
Extruded polystyrene (XPS), Type 4, 25.4mm	0.89
OSB sheathing, 11mm	0.11
Stud 38 x 89 mm $RSI_f = 0.757$ % area framing = 24.5 % Insulation $RSI_c = 2.46$ % area cavity = 75.5 %	1.59
Polyethylene (Vapour barrier)	-
Gypsum – interior finish (12.7mm)	0.08
Interior air film	0.12
	RSI_{eff} = 2.93 (m².K)/W

Note: Polyethylene Vapour retarder has a negligible contribution to effective thermal resistance

Tables for Calculating Effective Thermal Resistance of Opaque Assemblies

Natural Resources Canada (NRCan) has developed a document that provides designers with simple, easy-to-use look-up tables for the effective thermal resistance portions of assemblies containing both framing members and cavity insulation, as well as continuous layers (including air films). Essentially RSI series and RSIparallel are accounted for in these tables.

For most assemblies, the tables are organized as follows:

i. Type of assembly (e.g. walls above grade)
ii. Type of framing (e.g. dimensional lumber)
iii. Framing member size (e.g. 2" x 6")
iv. Framing on-centre spacing (e.g. 16") within each table

An example of a table is provided below for reference:

Walls Above and Not in Contact with Ground

Table WA-1
Walls Above Grade - Lumber Studs[1]
(Walls Above and Not in Contact with Ground)
Stud dimensional lumber - 38 mm x 89 mm (2"x4") with RSI=0.757 m²K/W

Cavity Insulation Component (Nominal Thermal Resistance)		Framing Configuration[2] (on-centre spacing)			
		304 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")
		Effective Thermal Resistance			
RSI	R	RSI	RSI	RSI	RSI
1.59	9	1.25	1.27	1.29	1.30
1.76	10	1.33	1.35	1.37	1.39
1.94	11	1.40	1.43	1.45	1.48
2.11	12	1.47	1.49	1.52	1.55
2.29	13	1.53	1.56	1.59	1.63
2.46	14	1.59	1.62	1.66	1.70
2.64	15	1.64	1.68	1.72	1.76
2.82	16	1.69	1.73	1.78	1.82
2.99	17	1.74	1.78	1.83	1.88
3.17	18	1.78	1.83	1.88	1.94
3.34	19	1.82	1.87	1.93	1.98
3.52	20	1.86	1.91	1.97	2.03
3.70	21	1.89	1.95	2.01	2.08

NOTES:

1) Continuous surface air films that are eligible to be added: Exterior air film 0.03 m²K/W, and interior wall air film 0.12 m²K/W.

2) Frame-Cavity Percentage	304 mm (12")	406 mm (16")	488 mm (19.2")	610 mm (24")
	24.5% frame 75.5% cavity	23% frame 77% cavity	21.5% frame 78.5% cavity	20% frame 80% cavity

APPENDIX D

TEMPERATURE DATA FOR LOCATIONS ACROSS CANADA

NOTES CONCERNING TEMPERATURE DATA

1. All temperature information is listed alphabetically within each province and territory.
2. Temperature data is provided in °F and °C.
3. Outdoor Design Temperatures for heating are based on January temperatures when 2-1/2% of the time the temperature will go below the listed temperature for short periods of time.
4. Outdoor Design Temperatures for cooling are based on July temperatures when 2-1/2% of the time the temperature will go above the listed temperature for short periods of time.
5. The Summer Mean Daily Temperature Range reflects the average range of temperature that can be expected.
6. Data is taken from Environment Canada, Atmospheric Environment Data, and conversions are made from metric to imperial.

LOCATION	North Lat.	Outdoor Design Temp Heating		Outdoor Design Temp Cooling		Summer Mean Daily Temp Range		Deep Ground Temp.	
	°	°F	°C	°F	°C	°F	°C	° F	°C
ALBERTA									
Athabasca	54.5	-31	-35	81	27	22	12	41	5
Banff	51	-24	-31	81	27	25	14	41	5
Barrhead	54	-27	-33	81	27	22	12	41	5
Beaverlodge	55	-33	-36	82	28	22	12	41	5
Brooks	50.5	-26	-32	90	32	25	14	45	7
Calgary	51	-22	-30	82	28	22	12	43	6
Campsie	54	-27	-33	81	27	25	14	41	5
Camrose	53	-27	-33	84	29	23	13	41	5
Canmore	52	-24	-31	82	28	25	14	43	6
Cardston	49	-20	-29	86	30	23	13	45	7
Claresholm	50	-22	-30	86	30	27	15	43	6
Cold Lake	54	-31	-35	82	28	20	11	39	4
Coleman	49.5	-24	-31	84	29	27	15	45	7
Coronation	52	-26	-32	86	30	23	13	41	5
Cowley	49	-20	-29	84	29	27	15	43	6
Drumheller	51	-26	-32	86	30	25	14	41	5
Edmonton	53.5	-22	-30	82	28	18	10	41	5
Edson	53.5	-29	-34	81	27	23	13	41	5
Embarras Portage	58	-42	-41	82	28	20	11	37	3
Fairview	56	-35	-37	81	27	20	11	39	4
Ford MacLeod	49	-22	-30	88	31	27	15	46	8
Fort McMurray	56.5	-36	-38	82	28	22	12	39	4
Fort Saskatchewan	53.5	-26	-32	82	28	23	13	41	5
Fort Vermilion	58	-42	-41	82	28	22	12	39	4
Grand Prairie	55	-33	-36	81	27	22	12	41	5
Habay	58.5	-42	-41	82	28	23	13	39	4
Hardisky	52.5	-27	-33	86	30	23	13	41	5

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
ALBERTA									
High River	50.5	-24	-31	82	28	27	15	43	6
Hinton	53	-29	-34	81	27	27	15	43	6
Jasper	52.5	-24	-31	82	28	22	12	43	6
Keg River	57.5	-40	-40	82	28	27	15	39	4
Lac la Biche	54.5	-31	-35	82	28	22	12	39	4
Lacombe	52	-27	-33	82	28	23	13	41	5
Lethbridge	49.5	-22	-30	88	31	25	14	46	8
Manning	56.5	-38	-39	81	27	20	11	39	4
Medicine Hat	50	-24	-31	90	32	23	13	46	8
Peace River	56	-35	-37	81	27	22	12	39	4
Pincher Creek	49	-20	-29	84	29	23	13	43	6
Ranfurly	53	-29	-34	84	29	22	12	41	5
Red Deer	52	-26	-32	82	28	23	13	41	5
Rocky Mountain House	52	-26	-32	81	27	23	13	41	5
Slave Lake	55	-31	-35	79	26	20	11	39	4
Stettler	52	-26	-32	86	30	25	14	41	5
Stony Plain	53.5	-26	-32	82	28	20	11	41	5
Suffield	50	-24	-31	90	32	27	15	46	8
Taber	49.5	-24	-31	88	31	27	15	46	8
Turner Valley	50.5	-24	-31	82	28	27	15	41	5
Valleyview	55	-35	-37	81	27	23	13	39	4
Vegreville	53.5	-29	-34	84	29	23	13	41	5
Vermilion	53	-31	-35	84	29	23	13	41	5
Wagner	55	-31	-35	79	26	22	12	39	4
Wainwright	52.5	-27	-33	84	29	22	12	41	5
Wetaskiwin	52.5	-27	-33	84	29	23	13	41	5
Whitecourt	54	-27	-33	81	27	22	12	41	5
Wimborne	51.5	-24	-31	84	29	23	13	41	5

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
BRITISH COLUMBIA									
100 Mile House	51	-22	-30	84	29	27	15	46	8
Abbotsford	49	18	-8	84	29	20	11	52	11
Agassiz	49	16	-9	88	31	18	10	52	11
Alberni	49	23	-5	88	31	23	13	50	10
Ashcroft	50	-11	-24	93	34	25	14	50	10
Bamfield	48	28	-2	73	23	14	8	52	11
Beatton River	57	-35	-37	79	26	23	13	39	4
Bella Bella	52	23	-5	73	23	14	8	50	10
Bella Coola	52	7	-14	81	27	20	11	50	10
Burnaby	52	19	-7	77	25	13	7	52	11
Burns Lake	54	-24	-31	79	26	29	16	43	6
Cache Creek	50.5	-11	-24	93	34	29	16	50	10
Campbell River	49.5	23	-5	79	26	16	9	50	10
Carmi	49	-11	-24	88	31	34	19	50	10
Castlegar	49	0	-18	90	32	27	15	50	10
Chetwynd	55	-31	-35	81	27	25	14	41	5
Chilliwack	49	16	-9	86	30	20	11	52	11
Cloverdale	49	18	-8	84	29	18	10	52	11
Comox	49.5	19	-7	81	27	14	8	50	10
Courtenay	49.5	19	-7	82	28	14	8	50	10
Cranbrook	49	-15	-26	90	32	23	13	48	9
Crescent Valley	49	0	-18	88	31	31	17	50	10
Crofton	48.5	25	-4	82	28	23	13	52	11
Dawson Creek	55.5	-36	-38	81	27	23	13	41	5
Dease Lake	58	-35	-37	75	24	20	11	39	4
Dog Creek	51	-18	-28	84	29	29	16	43	6
Duncan	48.5	21	-6	82	28	25	14	50	10
Elko	49	-18	-28	86	30	25	14	48	9
Fernie	49	-17	-27	86	30	27	15	46	8
Fort Nelson	58.5	-38	-39	82	28	22	12	39	4
Fort St. John	56	-31	-35	79	26	18	10	41	5
Glacier	51	-17	-27	81	27	22	12	46	8
Gold River	49	18	-8	88	31	23	13	52	11
Golden	51	-17	-27	86	30	25	14	46	8
Grand Forks	49	-2	-19	93	34	29	16	50	10
Greenwood	49	-4	-20	93	34	31	17	50	10
Haney	49	16	-9	86	30	22	12	52	11
Hope	49	9	-13	88	31	18	10	52	11
Jordan River	50.5	30	-1	72	22	13	7	54	12
Kamloops	50.5	-9	-23	93	34	23	13	50	10
Kaslo	49.5	1	-17	86	30	23	13	48	9
Kelowna	49.5	1	-17	91	33	27	15	52	11
Kimberley	49.5	-13	-25	88	31	29	16	46	8
Kitimat Plant	54	3	-16	77	25	18	10	45	7
Kitimat Townsite	54	3	-16	75	24	18	10	48	9
Ladner	50	21	-6	81	27	13	7	54	12
Ladysmith	49	19	-7	81	27	22	12	52	11
Langford	49	25	-4	81	27	18	10	54	12
Langley	49	18	-8	84	29	20	11	52	11

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	Outdoor Design Temp Heating °C	Outdoor Design Temp Cooling °F	Outdoor Design Temp Cooling °C	Summer Mean Daily Temp Range °F	Summer Mean Daily Temp Range °C	Deep Ground Temp. °F	Deep Ground Temp. °C
BRITISH COLUMBIA									
Lillooet	50.5	-6	-21	93	34	23	13	52	11
Lytton	50	1	-17	95	35	22	12	52	11
Mackenzie	55	-29	-34	81	27	22	12	41	5
Masset	54	23	-5	63	17	13	7	50	10
McBride	53	-20	-29	84	29	25	14	46	8
McLeod Lake	54.5	-31	-35	81	27	22	12	41	5
Merritt	50	-11	-24	93	34	27	15	52	11
Mission City	49	16	-9	86	30	18	10	52	11
Montrose	49	3	-16	90	32	31	17	50	10
Nakusp	50	-4	-20	88	31	22	12	48	9
Nanaimo	49	21	-6	81	27	16	9	52	11
Nelson	49	0	-18	88	31	23	13	50	10
New Westminster	49	18	-8	84	29	18	10	52	11
North Vancouver	49	19	-7	79	26	18	10	52	11
Ocean Falls	52	14	-10	73	23	13	7	46	8
Osoyoos	49	7	-14	95	35	27	15	54	12
Parksville	49	21	-6	79	26	16	9	54	12
Penticton	49	5	-15	91	33	23	13	52	11
Port Alberni	49	23	-5	88	31	23	13	50	10
Port Alice	50	27	-3	79	26	16	9	52	11
Port Hardy	50	23	-5	68	20	13	7	50	10
Port McNeill	50	23	-5	72	22	14	8	50	10
Port Renfrew	48	27	-3	75	24	16	9	52	11
Powell River	49.5	19	-7	79	26	14	8	52	11
Prince George	53.5	-26	-32	82	28	22	12	43	6
Prince Rupert	54	9	-13	66	19	11	6	50	10
Princeton	49	-11	-24	91	33	29	16	50	10
Qualicum Beach	49	19	-7	81	27	18	10	50	10
Queen Charlotte City	53	21	-6	70	21	9	5	50	10
Quesnel	52	-24	-31	86	30	25	14	43	6
Revelstoke	50.5	-4	-20	88	31	22	12	48	9
Richmond	49	19	-7	81	27	13	7	52	11
Salmon Arm	50.5	-2	-19	91	33	25	14	50	10
Sandspit	53	25	-4	64	18	9	5	52	11
Sechelt	49	21	-6	81	27	16	9	54	12
Sidney	48	25	-4	79	26	18	10	54	12
Smith River	59.5	-49	-45	79	26	20	11	39	4
Smithers	54.5	-20	-29	79	26	22	12	43	6
Sooke	48	30	-1	70	21	11	6	52	11
Squamish	49.5	16	-9	84	29	20	11	52	11
Stewart	55.5	1	-17	77	25	16	9	46	8
Surrey (88 Ave & 156 St.)	48	18	-8	84	29	20	11	54	12
Tahsis	50	25	-4	79	26	22	12	52	11
Taylor	56	-31	-35	79	26	23	13	41	5
Terrace	54	-2	-19	81	27	16	9	45	7
Tofino	49	28	-2	68	20	14	8	52	11

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
BRITISH COLUMBIA									
Lillooet	50.5	-6	-21	93	34	23	13	52	11
Lytton	50	1	-17	95	35	22	12	52	11
Mackenzie	55	-29	-34	81	27	22	12	41	5
Masset	54	23	-5	63	17	13	7	50	10
McBride	53	-20	-29	84	29	25	14	46	8
McLeod Lake	54.5	-31	-35	81	27	22	12	41	5
Merritt	50	-11	-24	93	34	27	15	52	11
Mission City	49	16	-9	86	30	18	10	52	11
Montrose	49	3	-16	90	32	31	17	50	10
Nakusp	50	-4	-20	88	31	22	12	48	9
Nanaimo	49	21	-6	81	27	16	9	52	11
Nelson	49	0	-18	88	31	23	13	50	10
New Westminster	49	18	-8	84	29	18	10	52	11
North Vancouver	49	19	-7	79	26	18	10	52	11
Ocean Falls	52	14	-10	73	23	13	7	46	8
Osoyoos	49	7	-14	95	35	27	15	54	12
Parksville	49	21	-6	79	26	16	9	54	12
Penticton	49	5	-15	91	33	23	13	52	11
Port Alberni	49	23	-5	88	31	23	13	50	10
Port Alice	50	27	-3	79	26	16	9	52	11
Port Hardy	50	23	-5	68	20	13	7	50	10
Port McNeill	50	23	-5	72	22	14	8	50	10
Port Renfrew	48	27	-3	75	24	16	9	52	11
Powell River	49.5	19	-7	79	26	14	8	52	11
Prince George	53.5	-26	-32	82	28	22	12	43	6
Prince Rupert	54	9	-13	66	19	11	6	50	10
Princeton	49	-11	-24	91	33	29	16	50	10
Qualicum Beach	49	19	-7	81	27	18	10	50	10
Queen Charlotte City	53	21	-6	70	21	9	5	50	10
Quesnel	52	-24	-31	86	30	25	14	43	6
Revelstoke	50.5	-4	-20	88	31	22	12	48	9
Richmond	49	19	-7	81	27	13	7	52	11
Salmon Arm	50.5	-2	-19	91	33	25	14	50	10
Sandspit	53	25	-4	64	18	9	5	52	11
Sechelt	49	21	-6	81	27	16	9	54	12
Sidney	48	25	-4	79	26	18	10	54	12
Smith River	59.5	-49	-45	79	26	20	11	39	4
Smithers	54.5	-20	-29	79	26	22	12	43	6
Sooke	48	30	-1	70	21	11	6	52	11
Squamish	49.5	16	-9	84	29	20	11	52	11
Stewart	55.5	1	-17	77	25	16	9	46	8
Surrey (88 Ave & 156 St.)	48	18	-8	84	29	20	11	54	12
Tahsis	50	25	-4	79	26	22	12	52	11
Taylor	56	-31	-35	79	26	23	13	41	5
Terrace	54	-2	-19	81	27	16	9	45	7
Tofino	49	28	-2	68	20	14	8	52	11

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
BRITISH COLUMBIA									
Trail	49	7	-14	91	33	25	14	50	10
Ucluelet	48.5	28	-2	64	18	9	5	52	11
Vancouver (city hall)	49	19	-7	82	28	13	7	52	11
Vancouver (Granville & 41 Ave)	49	21	-6	82	28	16	9	54	12
West Vancouver	49	19	-7	82	28	16	9	54	12
Whistler	43	1	-17	86	30	25	14	48	9
White Rock	48	23	-5	77	25	14	8	54	12
Williams Lake	52	-22	-30	84	29	22	12	45	7
Youbou	48.5	23	-5	88	31	22	12	50	10

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
MANITOBA									
Beausejour	50	-27	-33	84	29	23	13	43	6
Boissevain	49	-26	-32	86	30	22	12	43	6
Brandon	49.5	-27	-33	86	30	23	13	43	6
Churchill	58.5	-36	-38	77	25	14	8	30	-1
Dauphin	51	-27	-33	86	30	22	12	41	5
Flin Flon	54.5	-36	-38	81	27	18	10	39	4
Gimli	50.5	-29	-34	84	29	20	11	43	6
Island Lake	53.5	-33	-36	81	27	16	9	39	4
Lac du Bonnet	50	-29	-34	84	29	22	12	43	6
Lynn Lake	56.5	-40	-40	81	27	20	11	36	2
Morden	49	-24	-31	86	30	22	12	45	7
Neepawa	50	-26	-32	84	29	22	12	43	6
Pine Falls	50.5	-29	-34	82	28	22	12	43	6
Portage la Prairie	49.5	-24	-31	86	30	22	12	43	6
Rivers	50	-29	-34	84	29	25	14	43	6
Sandilands	49	-26	-32	84	29	23	13	43	6
Selkirk	50	-27	-33	84	29	22	12	43	6
Split Lake	56	-36	-38	81	27	20	11	34	1
Steinbach	49	-27	-33	84	29	23	13	43	6
Swan River	52	-29	-34	84	29	23	13	41	5
The Pas	53.5	-33	-36	82	28	18	10	41	5
Thompson	55.5	-40	-40	81	27	23	13	36	2
Virden	49.5	-27	-33	86	30	23	13	43	6
Winnipeg	49.5	-27	-33	86	30	22	12	43	6

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
NEW BRUNSWICK									
Alma	45.5	-6	-21	79	26	18	10	45	7
Bathurst	47.5	-9	-23	86	30	20	11	45	7
Campbellton	48	-15	-26	84	29	20	11	45	7
Edmundston	47	-17	-27	82	28	22	12	45	7
Fredericton	45.5	-11	-24	84	29	22	12	46	8
Gagetown	45.5	-11	-24	84	29	20	11	46	8
Grand Falls	47	-17	-27	82	28	20	11	45	7
Miramichi	47	-11	-24	86	30	20	11	45	7
Moncton	46	-9	-23	82	28	20	11	46	8
Oromocto	45.5	-11	-24	84	29	20	11	46	8
Sackville	45.5	-8	-22	81	27	18	10	46	8
Saint Andrews	47	-8	-22	77	25	18	10	46	8
Saint George	45	-6	-21	77	25	20	11	46	8
Saint John	45	-8	-22	77	25	18	10	45	7
Shippagan	47.5	-8	-22	82	28	16	9	36	2
St. Stephen	45	-11	-24	82	28	23	13	45	7
Woodstock	46	-15	-26	86	30	23	13	46	8

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
NEW FOUNDLAND									
Argentia	47	10	-12	70	21	9	5	46	8
Bonavista	48.5	7	-14	75	24	13	7	45	7
Buchans	48.5	-11	-24	81	27	16	9	43	6
Cape Harrison	54.5	-20	-29	79	26	14	8	41	5
Cape Race	46.5	12	-11	66	19	9	5	45	7
Channel-Port aux	48.5	9	-13	66	19	11	6	45	7
Corner Brook	48.5	3	-16	79	26	16	9	46	8
Gander	47	0	-18	81	27	16	9	45	7
Grand Bank	48.5	7	-14	68	20	13	7	46	8
Grand Falls	53	-15	-26	81	27	20	11	45	7
Happy Valley-Goose Bay	52.5	-24	-31	81	27	18	10	41	5
Labrador City	51	-33	-36	75	24	18	10	37	3
St. Anthony	47	-13	-25	72	22	13	7	41	5
St. John's	48.5	5	-15	75	24	14	8	45	7
Stephenville	53.5	3	-16	75	24	13	7	46	8
Twin Falls	47.5	-31	-35	75	24	16	9	39	4
Wabana	52.5	5	-15	75	24	14	8	45	7
Wabush	48.5	-33	-36	75	24	18	10	37	3

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
NOVA SCOTIA									
Amherst	45.5	-6	-21	81	27	16	9	46	8
Antigonish	45.5	1	-17	81	27	20	11	46	8
Bridgewater	44	5	-15	81	27	23	13	45	7
Canso	45	9	-13	77	25	11	6	46	8
Dartmouth	44.5	3	-16	79	26	14	8	46	8
Debert	45	-6	-21	81	27	22	12	45	7
Digby	44.5	5	-15	77	25	16	9	48	9
Greenwood (CFB)	45.5	0	-18	84	29	20	11	45	7
Halifax	44.5	3	-16	79	26	14	8	46	8
Kentville	45	0	-18	82	28	20	11	48	9
Liverpool	44	3	-16	81	27	13	7	48	9
Lockeport	43.5	7	-14	77	25	11	6	48	9
Louisburg	45.5	5	-15	79	26	14	8	46	8
Lunenburg	44	5	-15	79	26	13	7	46	8
New Glasgow	45.5	-2	-19	81	27	20	11	45	7
North Sydney	46	3	-16	81	27	18	10	46	8
Pictou	45.5	-2	-19	81	27	18	10	46	8
Port Hawkesbury	45.5	1	-17	81	27	16	9	46	8
Springhill	45.5	-4	-20	81	27	16	9	45	7
Stewiacke	45	-4	-20	81	27	20	11	45	7
Sydney	46	3	-16	81	27	16	9	46	8
Tatamagouche	45.5	-4	-20	81	27	20	11	46	8
Truro	45	-4	-20	81	27	22	12	45	7
Wolfville	45	-2	-19	82	28	20	11	48	9
Yarmouth	43.5	7	-14	72	22	13	7	48	9

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
NORTHWEST TERRITORIES									
Aklavik	68	-44	-42	79	26	16	9	28	-2
Echo Bay / Port Radium	66	-44	-42	72	22	14	8	30	-1
Fort Good Hope	66	-45	-43	82	28	20	11	32	0
Fort McPherson	67	-47	-44	79	26	16	9	28	-2
Fort Providence	61	-40	-40	82	28	23	13	37	3
Fort Resolution	61	-40	-40	79	26	20	11	36	2
Fort Simpson	61.5	-44	-42	82	28	20	11	36	2
Fort Smith	60	-42	-41	82	28	20	11	37	3
Hay River	60.5	-36	-38	81	27	16	9	37	3
Inuvik	68	-45	-43	79	26	16	9	28	-2
Mould Bay	76	-47	-44	52	11	7	4	16	-9
Norman Wells	65	-45	-43	82	28	18	10	32	0
Rae-Edzo	62.5	-44	-42	77	25	16	9	32	0
Tungsten	61.5	-56	-49	79	26	20	11	36	2
Ulukhaqtuuq / Holman	70	-38	-39	64	18	11	6	23	-5
Wrigley	63	-44	-42	82	28	23	13	32	0
Yellowknife	62	-42	-41	77	25	14	8	34	1

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
NUNAVUT									
Alert	82	-45	-43	55	13	7	4	14	-10
Arctic Bay	73	-44	-42	57	14	13	7	19	-7
Arviat	61	-40	-40	72	22	13	7	27	-3
Baker Lake	64	-44	-42	73	23	13	7	23	-5
Eureka	79.5	-53	-47	54	12	7	4	14	-10
Igluligaarjuk / Chesterfield Inl	63	-40	-40	68	20	13	7	25	-4
Iqaluit	69.5	-40	-40	63	17	11	6	27	-3
Iqaluktuuttiaq / Cambridge Bay	69	-42	-41	64	18	11	6	19	-7
Isachsen	78.5	-51	-46	54	12	11	6	12	-11
Kangiqiniq / Rankin Inlet	62.5	-42	-41	70	21	11	6	25	-4
Kanngiqtugaapik / Clyde River	70	-40	-40	57	14	13	7	21	-6
Kugluktuk / Coppermine	67.5	-42	-41	73	23	13	7	25	-4
Nottingham Island	63	-35	-37	61	16	11	6	27	-3
Resolute	74.5	-44	-42	52	11	7	4	18	-8
Resolution Island	61	-26	-32	54	12	7	4	30	-1
Salliq / Coral Harbour	64	-42	-41	68	20	13	7	25	-4

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
ONTARIO									
Ailsa Craig	43	1	-17	86	30	22	12	50	10
Ajax	43.5	-4	-20	86	30	18	10	50	10
Alexandria	45	-11	-24	86	30	20	11	48	9
Alliston	44	-9	-23	84	29	22	12	48	9
Almonte	45	-15	-26	86	30	22	12	48	9
Armstrong	50	-35	-37	82	28	23	13	48	9
Arnprior	45	-17	-27	86	30	22	12	41	5
Atikokan	48	-27	-33	84	29	22	12	48	9
Attawapiskat	52	-35	-37	82	28	23	13	43	6
Aurora	44	-6	-21	86	30	18	10	48	9
Bancroft	45	-18	-28	84	29	25	14	46	8
Barrie	44	-11	-24	84	29	20	11	48	9
Barriefield	44	-8	-22	82	28	16	9	50	10
Beaverton	44	-11	-24	86	30	14	8	48	9
Belleville	44	-8	-22	84	29	18	10	50	10
Belmont	42.5	1	-17	86	30	18	10	50	10
Bracebridge	45	-15	-26	84	29	22	12	46	8
Bradford	44	-9	-23	86	30	22	12	48	9
Brampton	43	-2	-19	86	30	20	11	48	9
Brantford	44	0	-18	86	30	20	11	50	10
Brighton	44	-6	-21	84	29	18	10	50	10
Brockville	44	-9	-23	84	29	18	10	50	10
Burk's Falls	45	-15	-26	84	29	23	13	46	8
Burlington	43	1	-17	88	31	13	7	50	10
Cambridge	43	0	-18	84	29	22	12	50	10
Campbellford	44	-9	-23	86	30	22	12	48	9
Cannington	44	-11	-24	86	30	20	11	48	9
Carleton Place	45	-13	-25	86	30	23	13	48	9
Cavan	44	-9	-23	86	30	22	12	48	9
Centralia	43	1	-17	86	30	20	11	50	10
CFB Borden	44	-9	-23	84	29	23	13	46	8
Chapleau	47.5	-31	-35	81	27	22	12	43	6
Chatham	42	3	-16	88	31	18	10	52	11
Chesley	44	-2	-19	84	29	22	12	48	9
Clinton	43	1	-17	84	29	22	12	48	9
Coboconk	44	-13	-25	86	30	20	11	46	8
Cobourg	43.5	-6	-21	84	29	13	7	50	10
Cochrane	49	-29	-34	84	29	23	13	43	6
Colborne	44	-6	-21	84	29	13	7	50	10
Collingwood	44	-6	-21	84	29	14	8	46	8
Cornwall	45	-9	-23	86	30	18	10	48	9
Corunna	42	3	-16	88	31	20	11	50	10
Deep River	46	-20	-29	86	30	22	12	46	8
Deseronto	44	-8	-22	84	29	22	12	50	10
Dorchester	42.5	0	-18	86	30	18	10	50	10

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
ONTARIO									
Dorion	48.5	-27	-33	82	28	23	13	43	6
Dresden	42	3	-16	88	31	20	11	52	11
Dryden	49.5	-29	-34	82	28	20	11	43	6
Dundalk	44	-8	-22	84	29	20	11	46	8
Dunnville	42.5	5	-15	86	30	20	11	50	10
Durham	44	-4	-20	84	29	20	11	48	9
Dutton	42	3	-16	88	31	22	12	50	10
Earlton	47.5	-27	-33	84	29	22	12	43	6
Edison	49.5	-29	-34	82	28	25	14	43	6
Elliot Lake	46	-15	-26	84	29	20	11	45	7
Elmvale	44	-11	-24	84	29	22	12	46	8
Embro	43	-2	-19	86	30	22	12	50	10
Englehart	47.5	-27	-33	84	29	22	12	43	6
Espanola	46	-13	-25	84	29	25	14	46	8
Etobicoke	43	-4	-20	88	31	18	10	50	10
Exeter	43	1	-17	86	30	20	11	50	10
Fenelon Falls	44	-13	-25	86	30	22	12	48	9
Fergus	43.5	-4	-20	84	29	18	10	48	9
Forest	43	3	-16	88	31	20	11	50	10
Fort Erie	42.5	5	-15	86	30	18	10	50	10
Fort Erie (Ridgeway)	42.5	5	-15	86	30	18	10	50	10
Fort Frances	48.5	-27	-33	84	29	22	12	45	7
Gananoque	44	-8	-22	82	28	16	9	50	10
Geraldton	49.5	-33	-36	82	28	22	12	41	5
Glencoe	42.5	3	-16	88	31	22	12	52	11
Goderich	43.5	3	-16	84	29	16	9	48	9
Gore Bay	45.5	-11	-24	82	28	16	9	46	8
Graham	49	-31	-35	84	29	23	13	43	6
Gravenhurst (Muskoka Airport)	44.5	-15	-26	84	29	22	12	46	8
Grimsby	43	3	-16	86	30	20	11	50	10
Guelph	43	-2	-19	84	29	22	12	48	9
Guthrie	44	-11	-24	84	29	20	11	48	9
Haileybury	47	-26	-32	86	30	18	10	45	7
Haldimand (Caledonia)	43	0	-18	86	30	22	12	48	9
Haldimand (Hagersville)	42.5	1	-17	86	30	20	11	50	10
Haliburton	45	-17	-27	84	29	22	12	46	8
Halton Hills	43.5	-2	-19	86	30	25	14	48	9

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	Outdoor Design Temp Heating °C	Outdoor Design Temp Cooling °F	Outdoor Design Temp Cooling °C	Summer Mean Daily Temp Range °F	Summer Mean Daily Temp Range °C	Deep Ground Temp. °F	Deep Ground Temp. °C
ONTARIO									
Hamilton	43	1	-17	88	31	18	10	50	10
Hanover	44	-2	-19	84	29	23	13	48	9
Hastings	44	-11	-24	86	30	22	12	48	9
Hawkesbury	45	-13	-25	86	30	22	12	48	9
Hearst	49	-31	-35	84	29	23	13	41	5
Honey Harbour	44.5	-11	-24	84	29	18	10	46	8
Hornepayne	49	-35	-37	82	28	27	15	41	5
Huntsville	45	-15	-26	84	29	20	11	46	8
Ingersoll	43	0	-18	86	30	18	10	50	10
Iroquois Falls	48	-27	-33	84	29	25	14	41	5
Jellicoe	49.5	-33	-36	82	28	22	12	41	5
Kapuskasing	49	-29	-34	84	29	22	12	41	5
Kemptville	45	-13	-25	86	30	22	12	48	9
Kenora	49.5	-27	-33	82	28	16	9	43	6
Killaloe	45.5	-18	-28	86	30	25	14	46	8
Kincardine	44	1	-17	82	28	18	10	50	10
Kingston	44	-8	-22	82	28	16	9	50	10
Kinmount	44.5	-15	-26	84	29	23	13	48	9
Kirkland Lake	48	-27	-33	84	29	22	12	43	6
Kitchener	43	-2	-19	84	29	22	12	48	9
Kitchenuhmaykoosib	53	-36	-38	79	26	20	11	37	3
Lakefield	44	-11	-24	86	30	22	12	48	9
Lansdowne House	52	-36	-38	82	28	18	10	41	5
Leamington	42	5	-15	88	31	16	9	52	11
Lindsay	44	-11	-24	86	30	22	12	48	9
Lion's Head	44.5	-2	-19	81	27	18	10	46	8
Listowel	43.5	-2	-19	84	29	20	11	48	9
London	42.5	0	-18	86	30	18	10	50	10
Lucan	43	1	-17	86	30	22	12	50	10
Maitland	44	-9	-23	84	29	18	10	50	10
Markdale	44	-4	-20	84	29	20	11	46	8
Markham	43	-6	-21	88	31	20	11	50	10
Martin	49	-31	-35	84	29	23	13	43	6
Matheson	48	-27	-33	84	29	23	13	43	6
Mattawa	46	-20	-29	86	30	22	12	46	8
Midland	44.5	-11	-24	84	29	18	10	46	8
Milton	43	0	-18	86	30	22	12	50	10
Milverton	43.5	-2	-19	84	29	20	11	48	9
Minden	44.5	-17	-27	84	29	25	14	46	8
Mississauga	43.5	0	-18	86	30	16	9	50	10
Mississauga (LBP Int'l Airport)	43.5	-4	-20	88	31	18	10	50	10
Mississauga(Port Credit)	43.5	0	-18	84	29	16	9	50	10
Mitchell	43	0	-18	84	29	22	12	48	9

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
ONTARIO									
Moosonee	51	-33	-36	82	28	22	12	41	5
Morrisburg	44.5	-9	-23	86	30	22	12	48	9
Mount Forest	43.5	-6	-21	82	28	18	10	48	9
Nakina	50	-33	-36	82	28	22	12	41	5
Nanticoke (Jarvis)	42.5	1	-17	86	30	20	11	50	10
Nanticoke (Port Dover)	42.5	5	-15	86	30	18	10	50	10
Napanee	44	-8	-22	84	29	22	12	48	9
New Liskeard	47.5	-26	-32	86	30	23	13	45	7
Newcastle	43.5	-4	-20	86	30	20	11	48	9
Newcastle	43.5	-4	-20	86	30	20	11	50	10
Newmarket	44	-8	-22	86	30	20	11	48	9
Niagara Falls	43	3	-16	86	30	18	10	50	10
North Bay	46	-18	-28	82	28	16	9	45	7
North York	43	-4	-20	88	31	22	12	50	10
Norwood	44	-11	-24	86	30	22	12	48	9
Oakville	43	0	-18	86	30	20	11	50	10
Orangeville	43.5	-6	-21	84	29	22	12	46	8
Orillia	44.5	-13	-25	84	29	18	10	46	8
Oshawa	43.5	-2	-19	86	30	20	11	50	10
Ottawa (Barrhaven)	45	-13	-25	86	30	18	10	48	9
Ottawa (city hall)	45	-13	-25	86	30	20	11	50	10
Ottawa (Kanata)	45	-13	-25	86	30	18	10	48	9
Ottawa (Int'l Airport)	45	-13	-25	86	30	18	10	48	9
Ottawa (Orleans)	45	-15	-26	86	30	20	11	46	8
Owen Sound	44	-2	-19	84	29	18	10	48	9
Pagwa River	50	-31	-35	82	28	23	13	41	5
Paris	43	0	-18	86	30	20	11	50	10
Parkhill	43	3	-16	88	31	20	11	50	10
Parry Sound	45	-11	-24	82	28	16	9	46	8
Pelham (Fonthill)	43	5	-15	86	30	16	9	52	11
Pembroke	45.5	-18	-28	86	30	23	13	46	8
Penetanguishene	44.5	-11	-24	84	29	18	10	48	9
Perth	44.5	-13	-25	86	30	22	12	48	9
Petawawa	45.5	-20	-29	86	30	23	13	46	8
Peterborough	44	-9	-23	86	30	22	12	48	9
Petrolia	42.5	3	-16	88	31	22	12	50	10
Pickering(Dunbarton)	43.5	-2	-19	86	30	16	9	50	10
Picton	44	-6	-21	84	29	16	9	50	10
Plattsville	43	-2	-19	84	29	20	11	50	10
Point Alexander	46	-20	-29	86	30	22	12	46	8
Port Burwell	42	5	-15	86	30	18	10	50	10
Port Colborne	42.5	5	-15	86	30	9	5	50	10
Port Elgin	44	1	-17	82	28	16	9	48	9
Port Hope	43.5	-6	-21	84	29	16	9	50	10
Port Perry	44	-8	-22	86	30	23	13	48	9
Port Stanley	42.5	5	-15	88	31	18	10	50	10

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
ONTARIO									
Prescott	44.5	-9	-23	84	29	18	10	50	10
Princeton	43	0	-18	86	30	22	12	50	10
Raith	48.5	-29	-34	82	28	29	16	43	6
Rayside Balfour	46	-18	-28	84	29	18	10	46	8
Red Lake	51	-31	-35	82	28	18	10	41	5
Renfrew	45	-17	-27	86	30	23	13	48	9
Richmond Hill	43.5	-6	-21	88	31	20	11	50	10
Rockland	45.5	-15	-26	86	30	22	12	50	10
Sarnia	42.5	3	-16	88	31	20	11	50	10
Sault Ste. Marie	46.5	-13	-25	84	29	20	11	46	8
Scarborough	43	-4	-20	88	31	18	10	50	10
Schreiber	48.5	-29	-34	81	27	18	10	41	5
Seaforth	43.5	1	-17	86	30	22	12	48	9
Shelburne	44	-8	-22	84	29	20	11	46	8
Simcoe	42.5	1	-17	86	30	20	11	50	10
Sioux Lookout	50	-29	-34	82	28	18	10	43	6
Smiths Falls	44.5	-13	-25	86	30	22	12	48	9
Smithville	43	3	-16	86	30	20	11	50	10
Smooth Rock Falls	49	-29	-34	84	29	22	12	41	5
South River	45.5	-17	-27	84	29	22	12	46	8
Southampton	44	1	-17	82	28	16	9	48	9
St. Catharines	43	3	-16	86	30	20	11	50	10
St. Mary's	43	0	-18	86	30	20	11	50	10
St. Thomas	42.5	3	-16	88	31	22	12	50	10
Stirling	44	-9	-23	86	30	23	13	48	9
Stratford	43	0	-18	84	29	20	11	48	9
Strathroy	42.5	1	-17	88	31	20	11	50	10
Sturgeon Falls	46	-18	-28	84	29	22	12	48	9
Sudbury	46.5	-18	-28	84	29	18	10	46	8
Sundridge	45.5	-17	-27	84	29	22	12	46	8
Tavistock	43	-2	-19	84	29	20	11	50	10
Temagami	47	-22	-30	86	30	18	10	46	8
Thamesford	43	-2	-19	86	30	18	10	50	10
Thedford	43	3	-16	88	31	20	11	50	10
Thunder Bay	48	-24	-31	84	29	22	12	43	6
Tillsonburg	42.5	1	-17	86	30	23	13	50	10
Timmins	48	-29	-34	84	29	22	12	41	5
Timmins (Porcupine)	48	-29	-34	84	29	22	12	43	6
Toronto (city hall)	43.5	0	-18	88	31	13	7	50	10
Trenton	44	-8	-22	84	29	18	10	50	10
Trout Creek	45.5	-17	-27	84	29	16	9	46	8

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	Outdoor Design Temp Heating °C	Outdoor Design Temp Cooling °F	Outdoor Design Temp Cooling °C	Summer Mean Daily Temp Range °F	Summer Mean Daily Temp Range °C	Deep Ground Temp. °F	Deep Ground Temp. °C
ONTARIO									
Uxbridge	44	-8	-22	86	30	22	12	48	9
Vaughan	49	-4	-20	88	31	22	12	50	10
Vittoria	42.5	5	-15	86	30	18	10	50	10
Walkerton	44	0	-18	86	30	23	13	48	9
Wallaceburg	42.5	3	-16	88	31	20	11	52	11
Waterloo	43.5	-2	-19	84	29	22	12	48	9
Watford	42.5	1	-17	88	31	20	11	50	10
Wawa	47.5	-29	-34	79	26	20	11	43	6
Welland	42.5	5	-15	86	30	20	11	50	10
West Lorne	42.5	3	-16	88	31	22	12	52	11
Whitby	43.5	-4	-20	86	30	16	9	50	10
Whitby (Brooklin)	43.5	-4	-20	86	30	20	11	48	9
White River	48.5	-38	-39	82	28	25	14	43	6
Wiarton	44.5	-2	-19	84	29	18	10	48	9
Windsor	42	3	-16	90	32	16	9	52	11
Wingham	43.5	0	-18	86	30	22	12	48	9
Woodstock	43	-2	-19	86	30	22	12	50	10
Wyoming	42.5	3	-16	88	31	20	11	50	10
PRINCE EDWARD ISLAND									
Charlottetown	46	-4	-20	79	26	16	9	46	8
Souris	46	-2	-19	81	27	11	6	46	8
Summerside	46	-4	-20	81	27	14	8	46	8
Tignish	46.5	-4	-20	81	27	11	6	48	9

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
QUEBEC									
Acton-Vale	45.5	-11	-24	86	30	22	12	46	8
Alma	48.5	-24	-31	82	28	20	11	43	6
Amos	48.5	-29	-34	82	28	22	12	43	6
Ancienne-Lorette	46.5	-13	-25	82	28	18	10	45	7
Asbestos	45.5	-15	-26	84	29	18	10	46	8
Aylmer	45	-13	-25	86	30	20	11	48	9
Baie-Comeau	49	-17	-27	77	25	16	9	43	6
Baie-Saint-Paul	49	-17	-27	82	28	20	11	45	7
Beaconsfield	45	-11	-24	86	30	18	10	48	9
Beauport	46.5	-15	-26	82	28	20	11	45	7
Bedford	45	-11	-24	84	29	2	1	48	9
Beloeil	45.5	-11	-24	86	30	20	11	48	9
Brome	46	-13	-25	84	29	22	12	46	8
Brossard	45	-11	-24	86	30	20	11	48	9
Buckingham	45.5	-15	-26	86	30	22	12	48	9
Campbell's Bay	45.5	-18	-28	86	30	23	13	48	9
Chambly	45	-11	-24	86	30	20	11	48	9
Coaticook	45	-13	-25	82	28	20	11	46	8
Contrecoeur	45.5	-13	-25	86	30	20	11	48	9
Cowansville	45	-13	-25	84	29	22	12	48	9
Deux-Montagnes	45	-13	-25	84	29	16	9	48	9
Dolbeau	48.5	-26	-32	82	28	22	12	46	6
Dorval	45.5	-11	-24	86	30	18	10	48	9
Drummondville	45.5	-15	-26	86	30	18	10	48	9
Farnham	45	-11	-24	84	29	20	11	48	9
Fort-Coulonge	45.5	-18	-28	86	30	23	13	48	9
Gagnon	51.5	-29	-34	75	24	18	10	39	4
Gaspe	48.5	-13	-25	79	26	22	12	45	7
Gatineau	45.5	-13	-25	86	30	20	11	48	9
Gracefield	46	-18	-28	86	30	22	12	46	8
Granby	45	-13	-25	84	29	18	10	46	8
Harrington-Harbour	50.5	-17	-27	66	19	13	7	45	7
Havre-St-Pierre	50	-17	-27	72	22	16	9	43	6
Hemmingford	45	-11	-24	86	30	22	12	48	9
Hull	45	-13	-25	86	30	20	11	48	9
Iberville	45	-11	-24	84	29	20	11	48	9
Inukjuak	58	-33	-36	70	21	11	6	30	-1
Joliette	46	-15	-26	84	29	22	12	46	8
Kuujjuaq	58	-35	-37	75	24	16	9	32	0
Kuujjuarapik	55	-33	-36	77	25	14	8	34	1
La Pocatiere	47	-11	-24	82	28	18	10	46	8
Lachute	45.5	-15	-26	84	29	20	11	48	9
Lac-Megantic	45.5	-17	-27	81	27	20	11	45	7
La-Malbaie	47.5	-15	-26	82	28	22	12	45	7
La-Tuque	47	-22	-30	84	29	23	13	45	7
Laval	45.5	-11	-24	84	29	20	11	48	9

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
QUEBEC									
Lennoxville	45	-18	-28	84	29	20	11	46	8
Lery	45	-11	-24	84	29	20	11	48	9
Levis	42	-13	-25	82	28	18	10	45	7
Loretteville	46.5	-15	-26	82	28	20	11	45	7
Louiseville	46	-13	-25	84	29	22	12	48	9
Magog	45	-15	-26	84	29	18	10	46	8
Malartic	48	-27	-33	84	29	22	12	43	6
Maniwaki	46	-22	-30	84	29	22	12	46	8
Masson	45.5	-15	-26	86	30	22	12	48	9
Matane	48.5	-11	-24	75	24	16	9	45	7
Mont-Joli	48.5	-11	-24	79	26	16	9	45	7
Mont-Laurier	46.5	-20	-29	84	29	23	13	45	7
Montmagny	46.5	-13	-25	82	28	20	11	45	7
Montreal (city hall)	45.5	-9	-23	86	30	14	8	48	9
Montreal-Est	45.5	-9	-23	86	30	16	9	48	9
Montreal-Nord	45.5	-11	-24	86	30	16	9	48	9
Nicolet (Gentilly)	46	-13	-25	84	29	18	10	48	9
Nitchequon	53	-38	-39	73	23	16	9	36	2
Noranda	48	-27	-33	84	29	18	10	43	6
Outremont	45.5	-9	-23	86	30	16	9	48	9
Perce	48.5	-6	-21	77	25	11	6	45	7
Pierrefonds	45	-11	-24	86	30	16	9	48	9
Pincourt	45	-11	-24	84	29	18	10	48	9
Plessisville	46	-15	-26	84	29	22	12	46	8
Port-Cartier	50	-18	-28	77	25	16	9	43	6
Puvinrituq	60	-33	-36	73	23	11	6	30	-1
Quebec	46.5	-13	-25	82	28	18	10	45	7
Richmond	45.5	-13	-25	84	29	22	12	45	7
Rimouski	48	-13	-25	79	26	18	10	45	7
RiviΦre-du-Loup	47.5	-13	-25	79	26	16	9	45	7
Roberval	48.5	-24	-31	82	28	18	10	43	6
Rock-Island	45	-13	-25	84	29	20	11	46	8
RosemΦre	45.5	-11	-24	84	29	20	11	48	9
Rouyn	48	-27	-33	84	29	18	10	43	6
Saguenay	48	-22	-30	82	28	20	11	43	6
Saguenay(Bagotville)	48	-24	-31	82	28	20	11	43	6
Saguenay (Jonquiere)	48	-22	-30	82	28	20	11	43	6
Saguenay(Kenogami)	48	-22	-30	82	28	20	11	43	6
Saint-Eustache	45	-13	-25	84	29	16	9	48	9

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C

QUEBEC

LOCATION	North Lat. °	Heating °F	Heating °C	Cooling °F	Cooling °C	Range °F	Range °C	Ground °F	Ground °C
Saint-Jean-sur-Richelieu	45	-11	-24	84	29	20	11	48	9
Salaberry-de-Valleyfield	45	-9	-23	84	29	18	10	48	9
Schefferville	54.5	-35	-37	75	24	16	9	34	1
Senneterre	48	-29	-34	84	29	23	13	43	6
Septiles	50	-20	-29	75	24	14	8	43	6
Shawinigan	46.5	-15	-26	84	29	20	11	46	8
Shawville	45.5	-17	-27	86	30	23	13	48	9
Sherbrooke	45	-18	-28	84	29	22	12	46	8
Sillery	46.5	-13	-25	82	28	18	10	45	7
Sorel	46	-13	-25	84	29	20	11	48	9
Ste-Agathe-des-Monts	46	-18	-28	82	28	20	11	45	7
Ste-Anne-de-Bellevue	45	-11	-24	84	29	18	10	48	9
Ste-Foy	46.5	-13	-25	82	28	18	10	45	7
St-Felicien	48.5	-26	-32	82	28	22	12	43	6
St-Georges-de-Cacouna	48	-13	-25	79	26	16	9	45	7
St-Hubert	45.5	-11	-24	86	30	20	11	48	9
St-Hubert-de-Riviere-du-Loup	47.5	-15	-26	79	26	20	11	43	6
St-Hyacinthe	45.5	-11	-24	86	30	20	11	48	9
St-Jerome	45.5	-15	-26	84	29	20	11	48	9
St-Jovite	46	-20	-29	82	28	25	14	45	7
St-Lambert	45.5	-9	-23	86	30	20	11	48	9
St-Laurent	45.5	-9	-23	86	30	18	10	48	9
St-Lazare-Hudson	50	-11	-24	86	30	23	13	46	8
St-Nicolas	46.5	-13	-25	82	28	18	10	45	7
Sutton	45	-13	-25	84	29	20	11	46	8
Tadoussac	48	-15	-26	81	27	18	10	45	7
Temiscaming	46.5	-22	-30	86	30	20	11	46	8
Terrebonne	45	-13	-25	84	29	20	11	46	8
Thetford Mines	46	-15	-26	82	28	18	10	45	7
Thurso	45.5	-15	-26	86	30	22	12	48	9
Trois-Rivieres	46	-13	-25	84	29	14	8	48	9
Val-d'Or	48	-27	-33	84	29	20	11	43	6
Varennes	45.5	-11	-24	86	30	20	11	48	9
Vercheres	45.5	-11	-24	86	30	20	11	48	9
Verdun	45	-9	-23	86	30	18	10	48	9
Victoriaville	46	-15	-26	84	29	20	11	46	8
Ville-Marie	47	-24	-31	86	30	20	11	45	7
Wakefield	45	-17	-27	86	30	23	13	46	8
Waterloo	45	-13	-25	84	29	22	12	48	9
Windsor	46	-13	-25	84	29	20	11	46	8

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
SASKATCHEWAN									
Assiniboia	49.5	-26	-32	88	31	23	13	45	7
Battrum	50.5	-26	-32	90	32	25	14	43	6
Biggar	52	-29	-34	86	30	23	13	43	6
Broadview	50	-29	-34	86	30	22	12	43	6
Dafoe	51.5	-31	-35	84	29	22	12	41	5
Dundurn	51.5	-31	-35	86	30	22	12	43	6
Estevan	49	-26	-32	90	32	23	13	43	6
Hudson Bay	52.5	-33	-36	84	29	23	13	41	5
Humboldt	52	-33	-36	82	28	23	13	41	5
Island Falls	55.5	-38	-39	81	27	22	12	39	4
Kamsack	51.5	-29	-34	84	29	25	14	41	5
Kindersley	51	-27	-33	88	31	23	13	43	6
Lloydminster	53	-29	-34	82	28	22	12	41	5
Maple Creek	49.5	-24	-31	88	31	25	14	45	7
Meadow Lake	54	-36	-38	82	28	22	12	39	4
Melfort	52.5	-33	-36	82	28	22	12	41	5
Melville	50.5	-29	-34	84	29	23	13	41	5
Moose Jaw	50	-26	-32	88	31	25	14	45	7
Nipawin	53	-35	-37	82	28	22	12	41	5
North Battleford	52.5	-29	-34	84	29	22	12	41	5
Prince Albert	53	-35	-37	82	28	22	12	41	5
Qu'Appelle	50.5	-29	-34	86	30	23	13	43	6
Regina	50	-29	-34	88	31	23	13	43	6
Rosetown	51.5	-29	-34	88	31	25	14	43	6
Saskatoon	52	-31	-35	86	30	23	13	43	6
Scott	52	-29	-34	86	30	23	13	41	5
Strasbourg	51	-29	-34	86	30	23	13	43	6
Swift Current	50	-24	-31	88	31	22	12	43	6
Uranium City	59.5	-44	-42	79	26	18	10	37	3
Weyburn	49.5	-27	-33	88	31	23	13	43	6
Yorkton	51	-29	-34	84	29	22	12	41	5

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	°C	Outdoor Design Temp Cooling °F	°C	Summer Mean Daily Temp Range °F	°C	Deep Ground Temp. °F	°C
YUKON TERRITORY									
Aishihik	61.5	-47	-44	73	23	23	13	36	2
Dawson	64	-58	-50	79	26	23	13	34	1
Destruction Bay	61	-45	-43	73	23	23	13	36	2
Faro	62	-51	-46	77	25	20	11	36	2
Haines Junction	60	-49	-45	75	24	23	13	37	3
Snag	62	-60	-51	73	23	23	13	36	2
Teslin	60	-44	-42	75	24	22	12	39	4
Watson Lake	60	-51	-46	79	26	20	11	39	4
whitehorse	60.5	-42	-41	77	25	20	11	37	3

LOCATION	North Lat. °	Outdoor Design Temp Heating °F	Outdoor Design Temp Heating °C	Outdoor Design Temp Cooling °F	Outdoor Design Temp Cooling °C	Summer Mean Daily Temp Range °F	Summer Mean Daily Temp Range °C	Deep Ground Temp. °F	Deep Ground Temp. °C
YUKON TERRITORY									
Aishihik	61.5	-47	-44	73	23	23	13	36	2
Dawson	64	-58	-50	79	26	23	13	34	1
Destruction Bay	61	-45	-43	73	23	23	13	36	2
Faro	62	-51	-46	77	25	20	11	36	2
Haines Junction	60	-49	-45	75	24	23	13	37	3
Snag	62	-60	-51	73	23	23	13	36	2
Teslin	60	-44	-42	75	24	22	12	39	4
Watson Lake	60	-51	-46	79	26	20	11	39	4
whitehorse	60.5	-42	-41	77	25	20	11	37	3